Halley At Its Best!

ASTRONOMY

March 1986
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How You Can See Halley's Comet

1986: The Year of the Shuttle

NASA's Space Station Takes Shape

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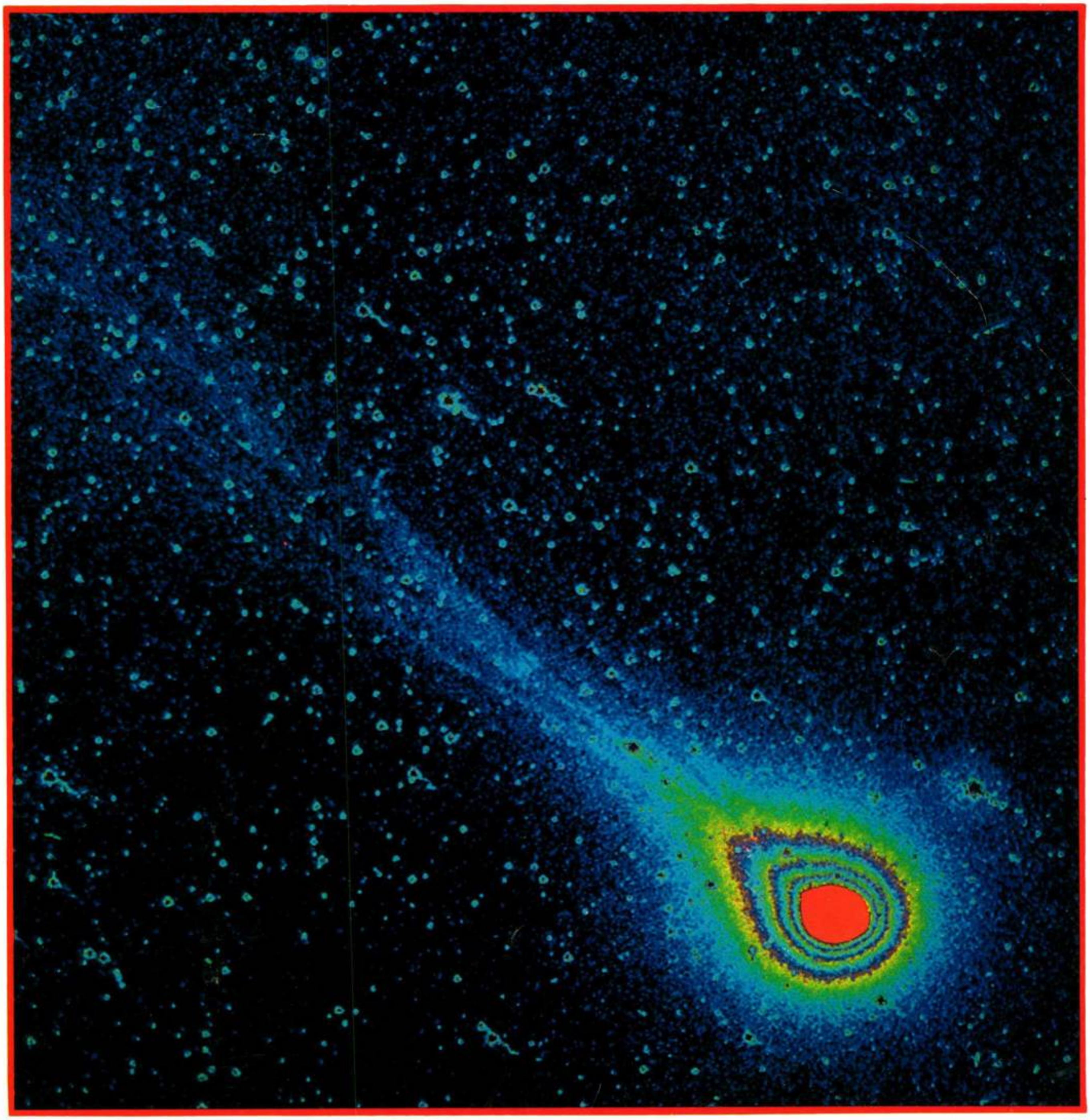

Halley's Emerging Tail

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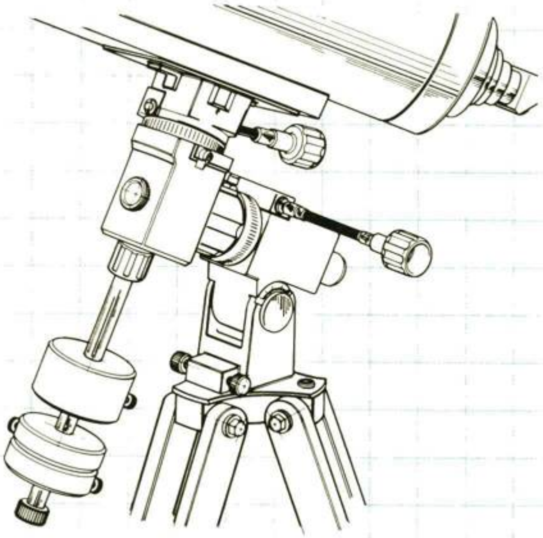
Meade® 1986 Product Forecast: More Innovation!

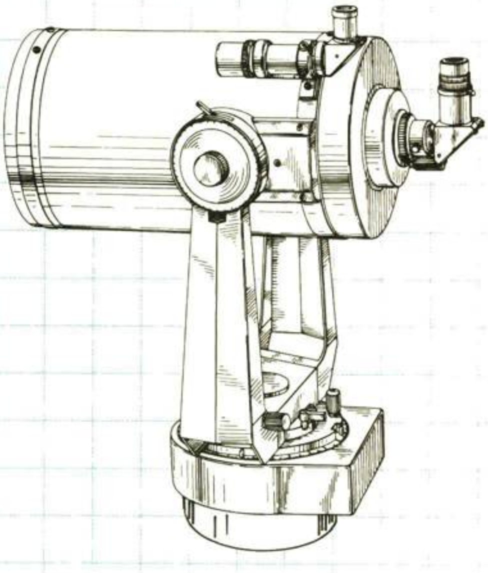
Revolutionary new telescope systems, a new World standard in premium-grade eyepieces, advanced-design accessories — and more.

As the World's leading manufacturer of astronomical telescopes for the serious amateur, Meade Instruments has been responsible for virtually every major innovation in commercial telescope design in recent history. Meade engineers and designers are constantly developing new and exciting products to expand your observations and photography of Earth and sky, and 1986 will see a wide range of important product introductions — telescopes and accessories at the leading edge of modern instrumentation. Here are the first examples of the product revolution that is taking place at Meade Instruments.*



Meade GEM Series 8″ and 10″ Schmidt-Cassegrains

Models 2080/GEM and 2120/GEM will include the exact same diffraction-limited optical performance, large apertures, and portability of the Meade Schmidt-Cassegrain design, but at more affordable price levels than Meade fork-mounted models. The German-type equatorial mountings, significantly larger and more stable than competing models, incorporate worm-gear controls on both axes. *An optional computer control system permits fully automatic slewing and object-location from a extensive pre-programmed library of deep-space objects.*



New Models 2080/LX4 and 2120/LX4 with Quartz Computerized Drives and Digital Slewing Systems

The most advanced computerized telescopes ever offered the serious amateur. Scheduled for introduction in June, these 8″ and 10″ Schmidt-Cassegrains will feature *optical encoders* that permit continuous digital coordinate readouts whether the telescope is slewed manually and/or electronically. At price levels of about $5000 (8″) to $7000 (10″) the LX4's will be well-suited to the sophisticated observer requiring the very finest in modern telescope technology.

New Accessories for the Meade Model 2080/LX3 8″ Schmidt-Cassegrain Telescope — now the World's most popular 8″ Schmidt-Cassegrain — include a highly-corrected wide-field telecompressor lens, variable polarizing eyepiece system, and a 45° erect-image diagonal prism for terrestrial observing, all available in April-May, 1986.

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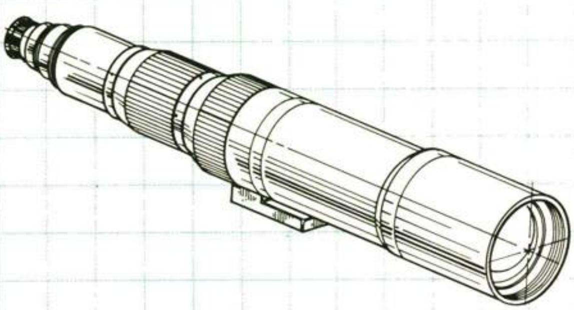
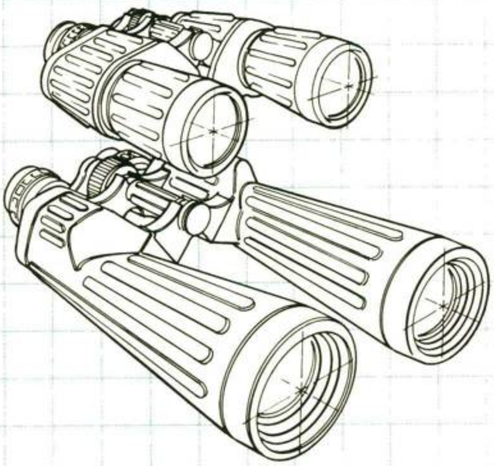
*All products described have April, 1986, introductory dates unless otherwise specified.



New Pathfinder™ Zoom Spotting Scope

The **Meade Pathfinder 15X – 60X 60mm Zoom Spotting Scope** is the first zoom terrestrial telescope to utilize the very latest in optical glass and design technology. *Included in its advanced 14-element optical system is a 3-element objective lens incorporating FK5 Low Dispersion Glass.* The resulting image is more highly corrected for both chromatic and spherical aberrations than previously possible in commercial zoom telescopes. Available either in standard textured-aluminum or in black rubber-armored models, the Pathfinder is also fully adaptable for thru-the-lens 35mm SLR photography.



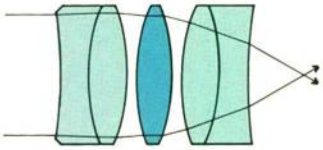
New Meade Binoculars

Meade Binoculars and Giant Astro Binoculars in over 20 models have been designed for the discriminating observer. Available in specifications from a compact 8 x 20mm to astronomical models 11 x 80mm, 20 x 80mm, and 30 x 80mm, and — for the first time — in rugged *rubber-armored giant 11 x 80mm and 20 x 80mm.* Several compact models of molded *carbon graphite* construction offer premium roof prism optics mounted in ultralight, extremely strong optical housings.

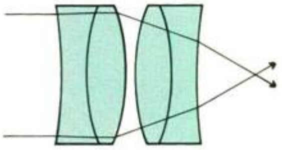
Meade Series 4000 Eyepieces: A New World Standard

Meade Super Plössl and Ultra Wide Angle Eyepieces in 18 focal lengths will be introduced in April and will, we believe, immediately set the standard against which all other eyepieces are measured. Totally new and revolutionary in design, *Meade Ultra Wide Angle eyepieces include 8-element optical systems with incredible 84° apparent fields,* consistent with pinpoint stellar images to the extreme field edge. *Meade Super Plössl eyepieces, with 5 optical elements rather than the traditional 4 (see diagrams), provide a 40% improvement in corrections for chromatic aberrations over other premium eyepieces.*

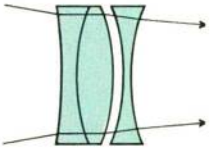
All-new **Meade Series 4000 2X and 2.8X Telenegative Amplifiers** will be introduced with the Series 4000 eyepieces. The most sophisticated Barlow lenses ever developed for commercial telescopes, Meade Models 140 and 142 Telenegative Amplifiers include *3-element, air-spaced, multi-coated optics,* and yield image resolution, color-correction, and extremely high image contrast levels never before possible to achieve in commercial optics.



Meade 5-Element Super Plössl Design



Other Premium Plössls: 4 Elements



Meade Series 4000 3-Element, Air-Spaced Barlow Lens

What else?

Several other major new Meade telescope systems will be announced later in the year, including a Meade super-large-aperture Schmidt-Cassegrain, now far along in development and designed for the advanced amateur or for the school or college observatory, at a price level of about $25,000. Watch this space for details!

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ASTRONOMY

Vol. 14, No. 3 March 1986

The World's Most Beautiful Astronomy Magazine

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Canadian Newsstand Dist.
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World Newsstand Distribution
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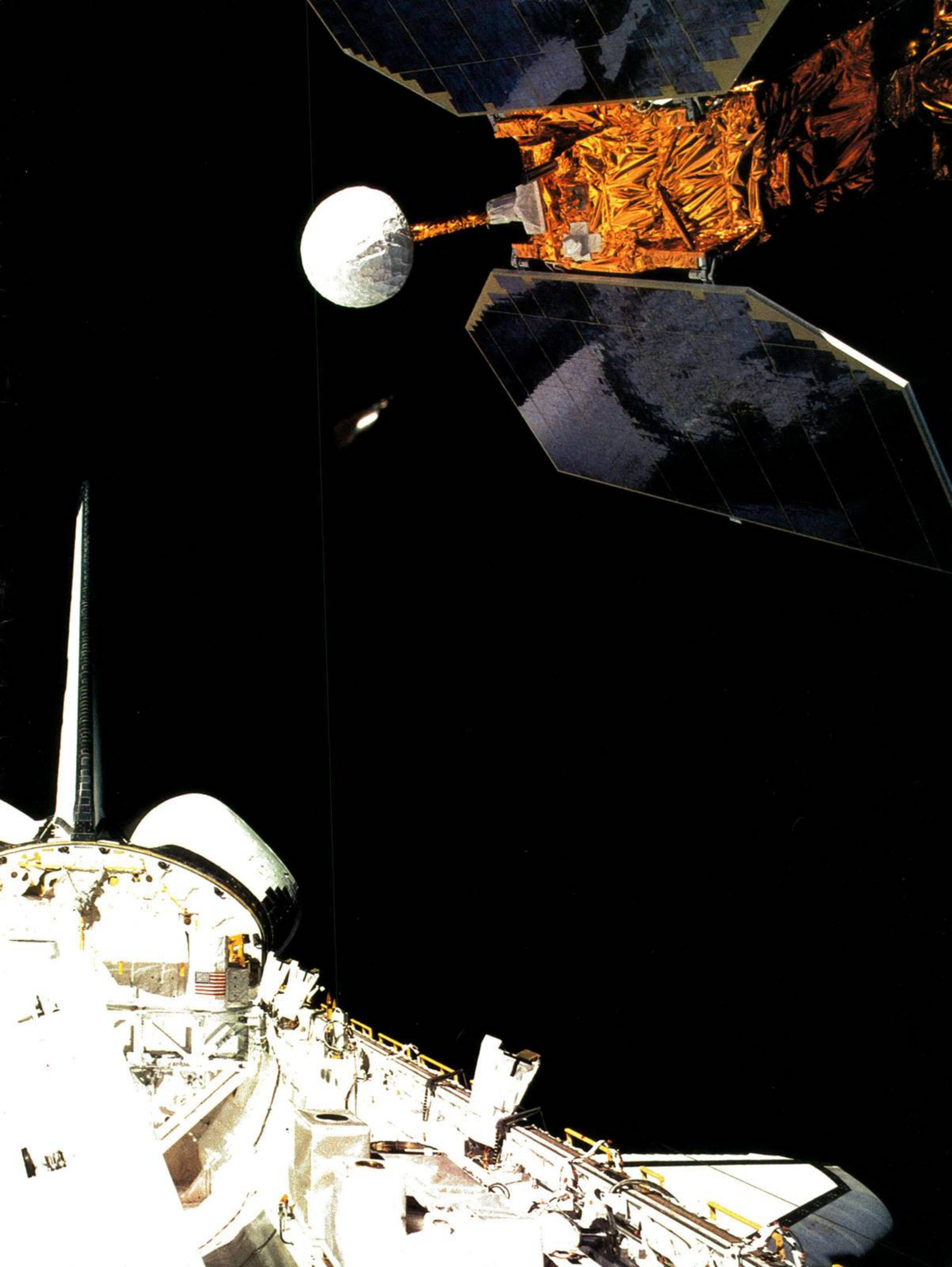
Cover: This month's cover photo is a digitized, false-color-coded image of Comet Halley made on the morning of November 9. It is a 12-minute exposure taken with an 8-inch f/1.5 Schmidt camera on hypersensitized Technical Pan film. The picture shows a tail three million miles long. Photo courtesy R.E. Schmidt, U.S. Naval Observatory. These pages: Shuttle flight 61-B taking off from its pad at Kennedy Space Center in Florida. NASA photo.

ASTRONOMY (ISSN 0091-6358) is published monthly by AstroMedia, a division of Kalmbach Publishing Co., 625 E. St. Paul Ave., P.O. Box 92788, Milwaukee, WI 53202. Copyright © 1985 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Second class postage paid at Milwaukee, WI and additional mailing offices. POSTMASTER: Send address changes to ASTRONOMY, P.O. Box 92788, Milwaukee, WI 53202. Questions about subscriptions and product orders: **(414) 276-8547** weekdays, 8am - 4pm. Allow six to eight weeks for new subscriptions and changes of address. New subscriptions start with current issue. Subscription price: 1 year, $21.00. All foreign: add $5.00 per year; please remit in U.S. funds. Send editorial and business inquiries and submissions to the address above. Telephone: (414) 276-2689. Not responsible for unsolicited materials. ASTRONOMY is indexed in *The Reader's Guide to Periodical Literature*. Microfilms of ASTRONOMY available from University Microfilms, Inc., 300 N. Zeeb Rd., Ann Arbor, MI 48106 and Bell & Howell Company, Old Mansfield Rd., Wooster, OH 46691. Printed in the U.S.A.

1986: A Busy Year For the Shuttle

A tight schedule of back-to-back flights will launch several important astronomical missions this year.

Photo courtesy of the Threshold Corporation, © Smithsonian Institution/Lockheed Corporation, 1985.



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This year marks the busiest yet for NASA's Space Transportation System, the Space Shuttle, and it is one that is dominated by missions of great astronomical importance. Payloads to be boosted into orbit include the two long-awaited deep-space missions Galileo and Ulysses, the Hubble Space Telescope, two missions to observe Comet Halley, three missions for stellar and galactic astronomy, plus seven commercial or Department of Defense flights. To accomplish this ambitious schedule, NASA will make use of all four Shuttle orbiters: Atlantis, Challenger, Columbia, and Discovery.

But, paradoxically, the Shuttle's impact on space science has been as negative as it has been positive this year. Space Shuttle cost overruns and delays contributed to the cancellation of NASA's own probe to Comet Halley as well as the American half of the joint European Space Agency/NASA International Solar Polar Mission (ISPM). (ESA's half of ISPM is now the Ulysses spacecraft.) The Galileo mission to Jupiter was delayed and then canceled because of the Shuttle's effect on NASA's budget. The mission was later reinstated.

Whatever the effect of the Space Shuttle, it is now a working system and this year will be its busiest yet. Launch scheduling is tight with an average of less than a month between lift-offs. Some are much closer: the European Ulysses and American Galileo missions are only six days apart. Timing is important for both because delays would reduce their scientific return.

Equally critical are the launch dates of the two flights to observe Comet Halley from Earth orbit. The Spartan mission, scheduled to observe Halley in late January just before the comet reaches perihelion, would have missed the comet altogether if the launch was delayed. Likewise, the Astro-1 telescope mission (Astro-Halley) must launch on time in order to photograph Comet Halley when the Russian, European, and Japanese spacecraft intercept the comet between March 6 and 15.

Five of this year's flights hold particular interest for astronomy. The Spartan and Astro-1 observatory missions will add valuable data to the major international scientific effort directed toward understanding Comet Halley. Ulysses is a European Space Agency (ESA) mission to explore space above and below the Sun's poles. Galileo is a sophisticated spacecraft sent on perhaps the most ambitious planetary mission ever: to determine the nature of the planet Jupiter and its large satellites. And the Space Telescope launch marks the beginning of a profound change in astronomy that will occur during the next decade.

The Hubble Space Telescope

The most significant Shuttle mission scheduled for this year is the launch of the Hubble Space Telescope (HST) in August. This $1.2-billion telescope will look deeper into space than any ground-based telescope ever has. From its orbital vantage point above Earth's turbulent and absorbent atmosphere, the quality of the Space Telescope's data will be unexcelled.

In a sense, the launch of HST marks the beginning of a new era. The early years of the space program were dominated by the planetary pathfinders. First came Rangers, Surveyors, and Lunar Orbiters to the Moon; next were Mariners to Venus, Mars, and Mercury; and then Pioneers to Jupiter and Saturn. These spacecraft took first looks and surveyed new worlds.

The second wave of exploration sought more. Vikings landed on Mars and mapped the entire planet from orbit. Voyager spacecraft journeyed to the giant planets (indeed, they're still going) and sent back a wealth of detail about worlds that were previously mere specks of light.

Galileo belongs to the third wave of planetary spacecraft that will probe deeply and precisely into questions of profound scientific interest. Part of a billion-dollar-apiece series cut short by NASA's funding difficulties, Galileo's exploration of Jupiter and its satellites promises to be fascinating. Galileo's questions aren't "what" questions but are "how" questions: How hot? How much?

The Hubble Space Telescope is the start of the second generation of space observatories. The pathfinders — Uhuru, Einstein, Copernicus, IUE, IRAS — gave astronomers glimpses of the sky in ultraviolet, x-ray, and infrared radiation; ground-based observatories served astronomers with their explorations in visible light. But HST will see farther and in more detail than all of these. It is the first of the great space observatories. Others will follow: the Advanced X-Ray Astrophysics Facility, the Gamma-Ray Observatory, and the Shuttle Infrared Telescope Facility will open the universe the same way the second-generation planetary spacecraft opened the Solar System.

Scheduled for launch aboard the Shuttle Atlantis on August 6, HST will first undergo a thirty-day engineering checkout. "First light," the first starlight to pass through the telescope, occurs roughly ten days after launch. Pictures demonstrating HST's full capabilities may take several more weeks to obtain. When the engineers finally declare the spacecraft fully operational, the scientists will take over for a "science verification" phase. Three months of this time will be devoted to learning how to use the telescope and calibrating its instruments. Then HST will probe the universe.

The astronomers who will reap the honor and glory resulting from the first full use of the most powerful telescope ever built aren't just anybody's astronomers. These guaranteed-time observers have "paid their dues" with ten years of involvement in building the instruments and getting HST off the ground. But HST is a national facility. Beginning six months after launch, any qualified astronomer can apply for observing time on the telescope as a general observer.

Observing proposals will be submitted annually with about 200 accepted each year; selection will be based on scientific merit. Competition will be fierce with only one proposal in ten winning acceptance. After a proposal is accepted, powerful computers will analyze the observing programs in terms of HST's operational constraints.

Depending on the type of investigation planned, an observer may come to the Space Telescope Science Institute in Baltimore to monitor what's going on and, possibly, to make real-time decisions. But HST has very limited hands-on capability; most observers will simply sit in an office and wait for their data to roll in. When the observing run ends, the astronomer will go home with reels of magnetic tape. Unlike the practice of many ground-based observatories, HST observers do not "own" their observations; the data is too valuable for that. Instead, for a year the observer alone has access to HST observations; therafter the data is in the public domain.

Tethered to Discovery, astronaut Joseph Allen wrestles the Indonesian communications satellite Palapa B-2 back into the Shuttle's cargo bay for return to Earth. The Shuttle recovered the stranded satellite after its rocket engine failed to loft Palapa into high orbit.

HST will influence astronomy in many different ways. Certainly the telescope is the most powerful, although not the largest, ever built. But just as important is the Space Telescope Science Institute, the organization and funding agency that manages HST. When an astronomer applies for observing time on the telescope, he or she will also apply for grant money to carry out the analysis of the telescope data just as many planetary scientists now depend on NASA funding to study data from missions to the planets. In a few years' time, the Institute will be funding astronomy with an amount roughly equal to the entire astronomy budget of the National Science Foundation! At this level of funding, the Space Telescope will determine the nature of astronomy in the coming decades.

The instruments that record, dissect, and measure the light collected by the Space Telescope's 94.5-inch primary mirror are the finest ever built. The key sensors are a versatile wide-field/planetary camera and a ultra-sensitive faint object camera. Two spectrographs will study the distribution of energy by wavelength, a faint object spectrograph will be used to determine the composition and redshifts of distant galaxies, and a high-resolution spectrograph will obtain detailed analyses of quasars, galaxies, and nebulae in ultraviolet light. To measure the brightness of a star, pulsar, or nova, astronomers will use a high-speed photometer. Finally, the fine guidance system is capable of determining the position of a celestial object with unparalleled precision.

The Shuttle initially serves HST as its delivery truck. Later, the Shuttle will bring in a maintenance crew to swap new instruments for old ones or to fix failed components. The aft instrument bay (the back end of HST) has been designed to accommodate astronauts and includes handholds, footrests, and even lights so a working astronaut can see what he's doing. Although HST could, in theory, be returned to the ground for refurbishing, it is not practical.

NASA's astronomers have set daunting goals for the Space Telescope. Using HST, they will "determine the constitution, physical characteristics, and dynamics of celestial entities; the nature of processes that occur in the extreme physical conditions in and between astronomical objects; the history and evolution of the universe; and whether the laws of nature are universal in the space-time continuum."

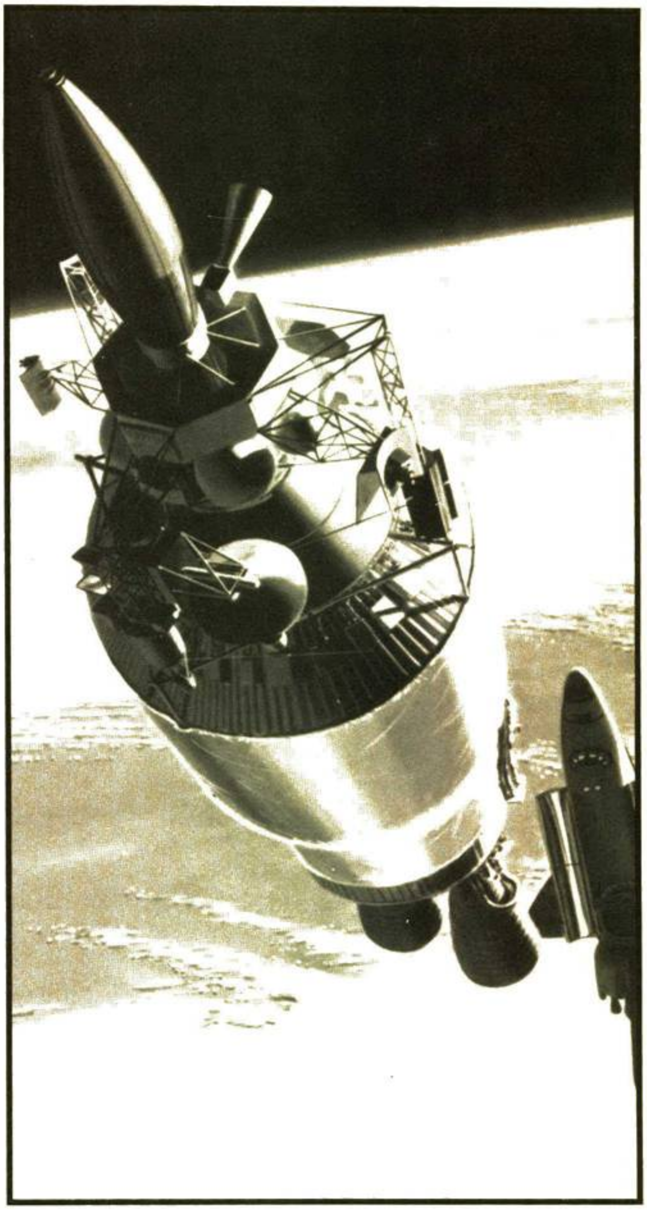
Few programs in the history of astronomy have attempted so much.

Galileo

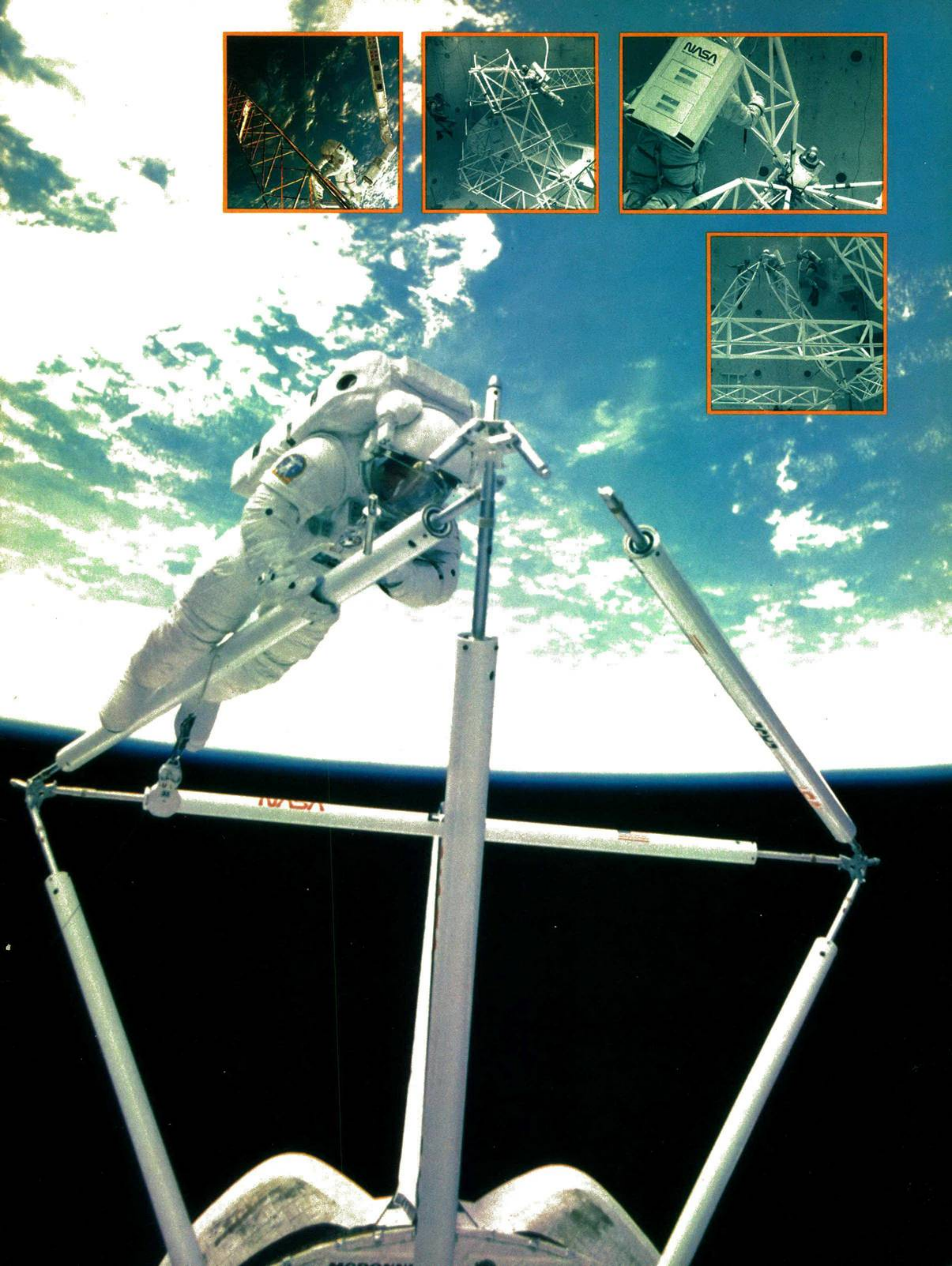
On May 21, if all goes well, Space Shuttle Atlantis will lift off from Kennedy Space Center's pad 39B with NASA's 5,622-pound Galileo Jupiter Orbiter and Probe stowed safely in its cargo bay. A few days later, the remote manipulator arm will lift the spacecraft into space and as flame spurts from the engine bell of the modified Centaur upper stage, Galileo will, at long last, be headed for Jupiter. It will arrive there in December 1988.

Plagued by a decade of launch vehicle changes, delays, and technical problems played out against the full panorama of civilian space agency politics and shifting national priorities, Galileo may be the last of NASA's billion-dollar planetary missions. (We now live in an era of hesitantly funded, budget-priced missions to the planets.) By almost any measure, Galileo is the most sophisticated planetary mission ever attempted. As its primary goal, Galileo will supply the data from which astronomers will learn about the chemical and physical state of Jupiter's atmosphere and selected jovian satellites and deduce the structure and dynamics of the jovian magnetosphere. To this end, the Galileo Orbiter will spend twenty-some months circling Jupiter, passing breathtakingly close to one satellite after another while photographing and measuring the planet and its satellites and sampling the magnetic fields and energetic particles surrounding them.

As it crosses the asteroid belt between Mars and Jupiter, Galileo will pass within 12,000 miles of the 125-mile diameter asteroid 29, named Amphitrite (pronounced am-fit-TRY-tee). If the spacecraft is healthy and everything goes smoothly, on December 7 of this year Galileo will become the first spacecraft to encounter an



Above: The Galileo mission will begin its flight to Jupiter in May after being launched from the Space Shuttle. Right: Astronaut Sherwood Spring connects components of the Experimental Assembly of Structures (EASE) experiment on mission 61-B, which was flown in November/December 1985. Overleaf: Commander Henry Hartsfield (left) and pilot Michael Coats sit in Discovery's forward cockpit during mission 41-D's September 1984 flight. Photo courtesy of the Threshold Corporation, © Smithsonian Institution/Lockheed Corporation, 1985.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asteroid. While Amphitrite is expected to look much like a bigger version of the martian satellites Deimos and Phobos, no asteroid has ever been observed at such close range before. The cameras will image features as small as 600 feet across; other instruments will study the mineralogy and composition of Amphitrite.

Five months before its encounter with Jupiter, the Galileo Probe will separate from the orbiter and set off on a trajectory that will end in a fiery descent into the jovian atmosphere. Protected by its heat shield, the intact probe will pop out a parachute as it slows. Instruments sampling the jovian atmosphere will radio their readings to the orbiter 120,000 miles away for relay to Earth. After the probe sinks through Jupiter's equatorial cloud layers for an hour, the orbiter will pass out of radio range. Pressure and heat will eventually destroy the probe.

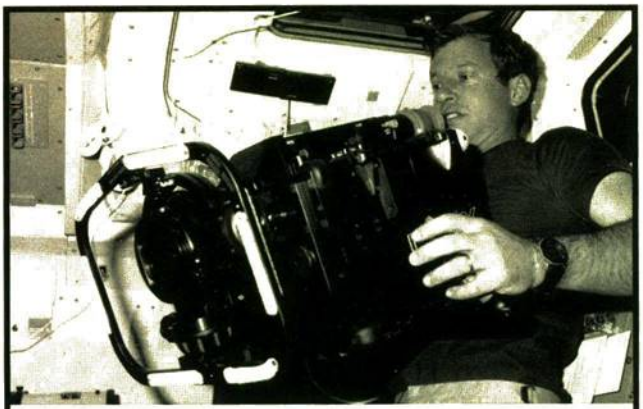
The orbiter will swing within 600 miles of the surface of Io — the innermost of Jupiter's big satellites — and then into a long, looping orbit about the giant planet. Without this maneuver it would continue past Jupiter, just as the Pioneer and Voyager spacecraft before it have done. On each circuit of the giant planet, the orbiter will pass close to one of Jupiter's largest satellites, using their gravity to alter its orbit and, in passing, studying the features and spectrum of the surface. The best pictures will show features down to 100 feet across — ten to several hundred times better than the best Voyager images.

In addition to precision camera eyes, Galileo will carry an infrared mapping spectrometer capable of producing infrared reflectivity and heat pictures of Jupiter and its satellites. An ultraviolet spectrometer will study short wavelength emissions from the upper jovian atmosphere, and a photopolarimeter will analyze subtle polarization properties of light reflected from the planet and its satellites and measure the heat energy coming from them. These data will tell astronomers about the composition and properties of the atmosphere. Other instruments will measure the charged particle and magnetic field environment of the spacecraft, the radio waves impinging on it, and the size and speed of dust particles in orbit about Jupiter.

"Galileo will produce just an incredible wealth of information," predicts W. Reid Thompson, a specialist in scientific computing, "but information is meaningless unless we can work with it and understand it." Unlike previous planetary missions, the 114 scientific investigators who will operate the eleven scientific instruments on board Galileo will process much of the information at their home institutions rather than the computer facilities at the Jet Propulsion Laboratory or NASA.

Ulysses

Just six days before Atlantis lifts off with Galileo, Challenger will boost from Kennedy Space Center carrying the European Space Agency's Ulysses mission into orbit. The 814-pound spacecraft, built for the ESA by Dornier Systems in West Germany, is one of two spacecraft delegated for the International Solar Polar Mission. Because of the difficulty in obtaining a launch date, the Ulysses spacecraft sat in cold storage from December 1983 until March 1985.



Space Shuttle Stars in *The Dream Is Alive*

"It's the closest thing to being there," say the astronauts who filmed it. Earthbound observers can experience an insider's view of the Shuttle — minus the space sickness — in the film *The Dream Is Alive*. Filmed for the Imax® super wide-screen theater with the Imax large-format camera, *The Dream Is Alive* features spectacular in-flight footage shot by the astronauts themselves on three separate missions. Dramatic Shuttle liftoffs, on-orbit satellite launches, the repair of the Solar Maximum Mission satellite, and zero-gee cabin interior shots are featured in the film. Some of these stunning images are reproduced on pages 6-7, 12-13, and 20-21 of this issue.

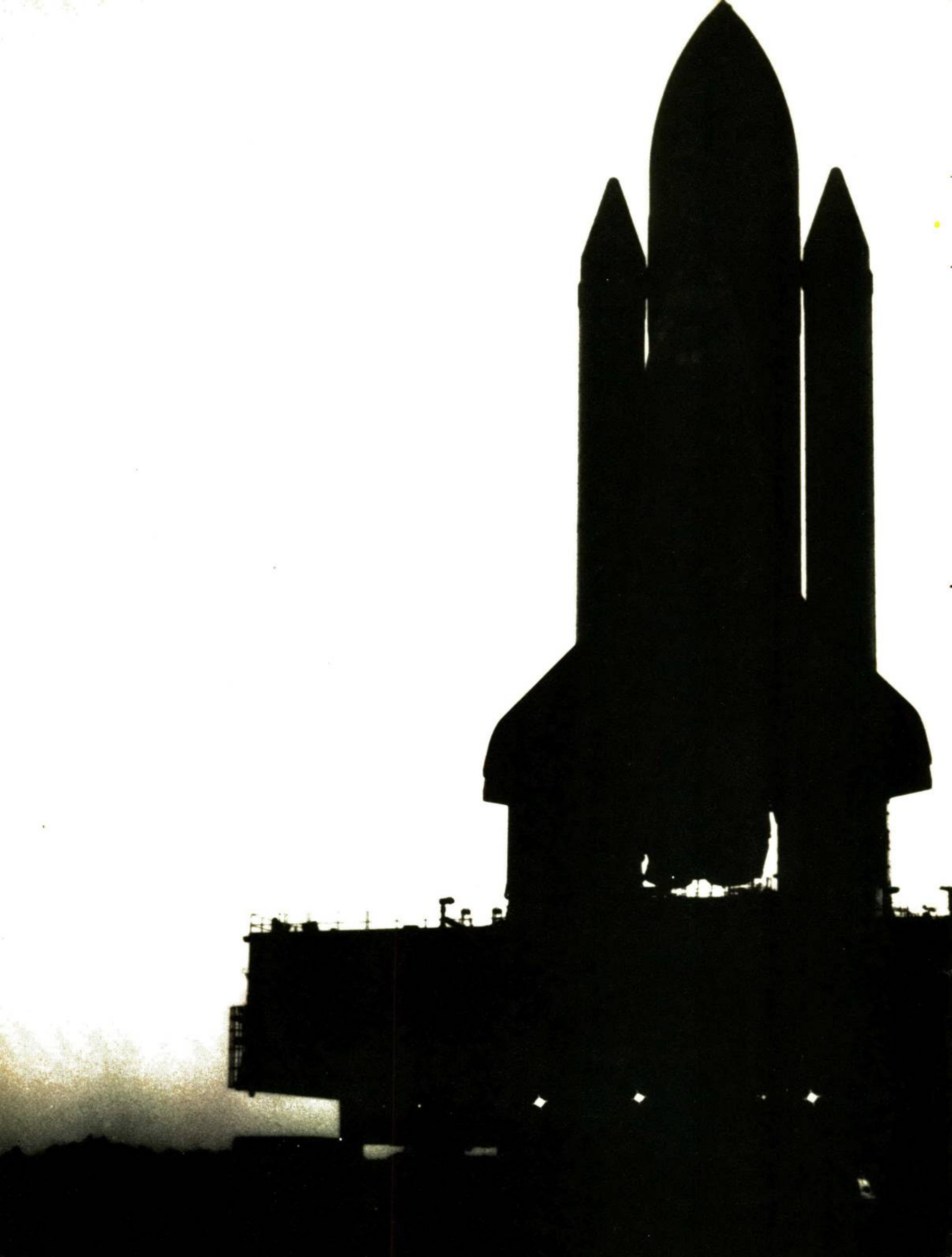
Imax film uses 70mm stock in a 15-perf-high format — the largest film frame in motion-picture history. The Toronto-based Imax Systems Corporation designs and builds cameras and projectors in this unique format and licenses their use worldwide. NASA's involvement came at the request of the Smithsonian Institution's National Air and Space Museum. In keeping with its charter mandate to disseminate information about the American space program, NASA allowed astronauts to train in the use of the Imax camera and permitted Imax filming at NASA centers around the country.

The Dream Is Alive is the product of a unique partnership between America's civilian space agency and private enterprise. Produced and directed by Graeme Ferguson for the National Air and Space Museum and jointly funded by the museum and the Lockheed Corporation as a public service, the 37-minute film was made to be shown on a 50- by 70-foot screen. Since its premiere at the National Air and Space Museum's Samuel P. Langley theater, *The Dream Is Alive* has been shown at many other Imax® and Omnimax® theaters; a listing of scheduled theater dates and locations can be acquired by phoning 416-960-8509.

The reason for the mission is simple: the Sun is the most important body in the Solar System, yet we have studied the solar wind and its magnetic fields only near the Sun's equator. Astronomers know very little about the conditions in space above and below the plane occupied by the orbits of the planets, yet this region may hold important clues to the Sun's behavior.

The Sun's polar regions have not been explored for a very good reason: the energy requirement to send a

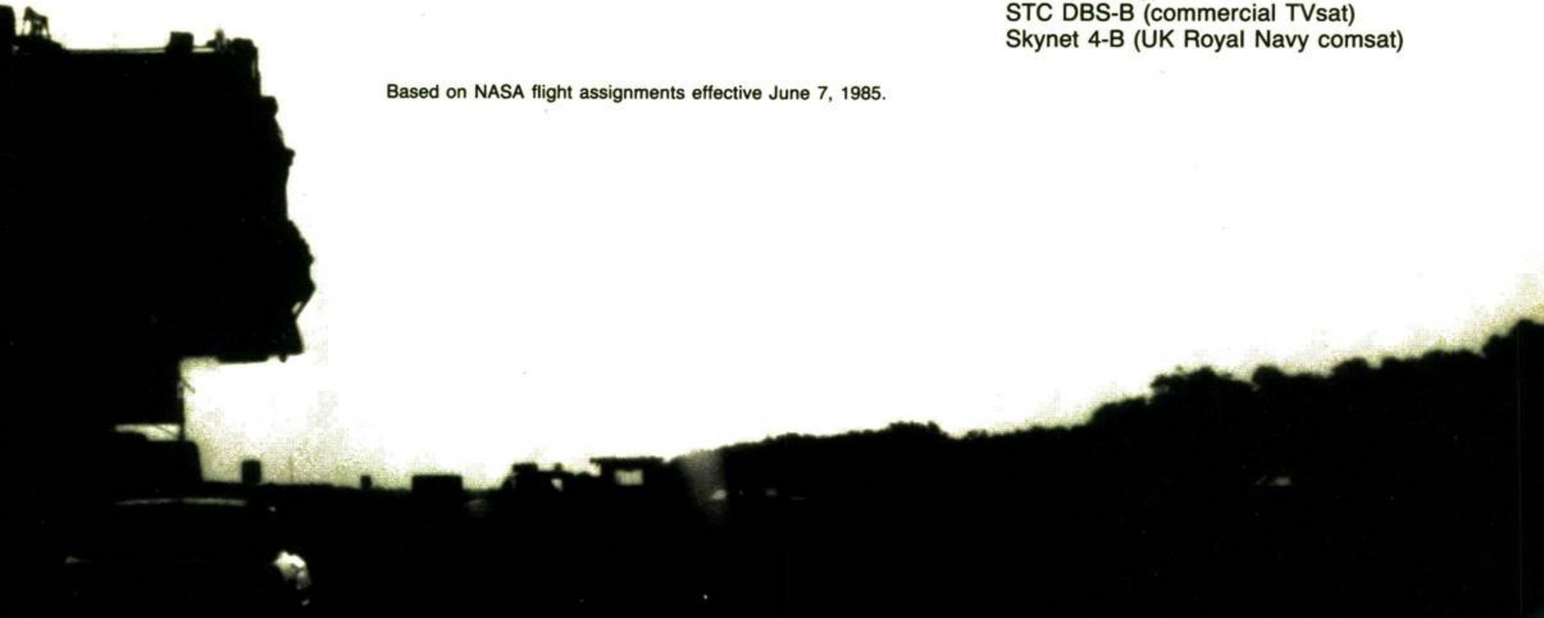
A sudden flare of light accompanies the firing of Challenger's port vernier rocket. Although the near-Shuttle environment is fine for many types of missions, highly sensitive instruments used for scientific work are best kept well away from the type of chemical and optical contamination caused by the Shuttle's rockets. Three times this year, low-cost Spartan spacecraft will carry instruments away from the Shuttle for better observations.



1986 Space Shuttle Launch Schedule

Mission	Shuttle	Launch Site	Launch Date	Other Payloads
51-L	Challenger	Kennedy	January 22	Spartan-Halley (UV spectroscopy) TDRS-B (NASA relay comsat)
61-E	Columbia	Kennedy	March 6	ASTRO-Halley (UV imaging) Westar 7 (Western Union comsat)
62-A	Discovery	Vandenburg	March 20	DOD payload
61-F	Challenger	Kennedy	May 15	Ulysses (ESA solar polar mission)
61-G	Atlantis	Kennedy	May 21	Galileo (NASA Jupiter mission)
61-H	Columbia	Kennedy	June 24	EOS-1 (pharmaceuticals) MSL-4 (materials science lab) Skynet 4-A (UK Royal Navy comsat) Palapa B-3 (Indonesian comsat)
61-M	Challenger	Kennedy	July 15	TDRS-D (NASA relay comsat) INSAT 1-C (Indian comsat)
61-J	Atlantis	Kennedy	August 8	Space Telescope (astronomy)
61-K	Columbia	Kennedy	September 3	EOM-1/2 (solar energy experiment)
61-I	Challenger	Kennedy	September 24	LDEF (space exposure experiment) Intelsat IV-1 (comsat)
62-B	Discovery	Vandenburg	September 29	DOD payload
61-L	Atlantis	Kennedy	October 22	SHEAL-1 (x-ray astronomy) MSL-5 (materials science lab) DOD (military) STC DBS-A (commercial TVsat) ASC-2 (commercial comsat)
71-A	Columbia	Kennedy	October 30	ASTRO-2 (ultraviolet observatory) Spartan-2 (solar physics) HS 376-R
71-B	Challenger	Kennedy	November 26	DOD payload
71-C	Atlantis	Kennedy	December 15	Spartan-3 (ultraviolet imaging) DOD (military) STC DBS-B (commercial TVsat) Skynet 4-B (UK Royal Navy comsat)

Based on NASA flight assignments effective June 7, 1985.



probe out of the plane of Earth's orbit is tremendous. No rocket made has enough power to shoot directly for the solar pole. Ulysses will instead take a roundabout route via Jupiter. After lift-off from the Shuttle cargo bay, Ulysses will boost out of Earth orbit atop a modified Centaur upper stage. This upper stage is a somewhat different version of the liquid hydrogen/oxygen-fueled vehicle that Galileo will use. Reaching Jupiter in July 1987 after traveling only fourteen months, Ulysses will zip under Jupiter's south pole and use the giant planet as a gravitational slingshot to rise high above the ecliptic plane.

Ulysses' trajectory will take it more than two astronomical units out of the orbital plane of the planets. As it moves back toward the Sun, the spacecraft's instruments will investigate the solar wind, x-rays from solar flares, cosmic gamma-ray bursts, and the Sun's magnetic field. In late 1989, Ulysses will fly over the Sun's north polar regions for a four-month period. It will then plunge toward the ecliptic, crossing it in July 1990, and continue toward the south pole, which it will pass over during four months in late 1990 and early 1991. The mission will end in March 1991.

Spartan-Halley

Spartan missions are designed to exploit the Shuttle's unique capabilities. These low-cost "toss-it-overboard" programs capitalize on the immense store of technical expertise available in university astronomy and physics departments. Spartan experiments are little more than glorified sounding-rocket payloads hooked up to a four-foot cube, the Spartan carrier. With batteries for power and a thousand-gigabit tape recorder to record data, the Spartan carrier offers astronomers cheap access to space.

Long before satellite observatories became available, rocket-launched payloads proved the worth of ultraviolet and x-ray astronomy. Although the payload might be above the atmosphere for only five minutes, the experiments were quick and cheap to build. Such rocket experiments are often produced "at home" in a university's "skunkworks" where they are designed by the scientist-experimenter and assembled by graduate students and technicians from off-the-shelf parts.

Tossed overboard for forty-eight hours of data-taking aboard Spartan, the experiment payload could make a major discovery that would not have been made had it been launched into space for five minutes by a rocket. More importantly, Spartan offers the astronomer cheap observing time. While satellite experiments offer a long working life, the effort of funding, building, qualifying, and flying a satellite experiment may prove to be a decade-long travail and very expensive.

This year there are two Spartan flights. At the time of this writing Spartan-Halley was scheduled to fly in late January, carrying with it two spectrometers and two space-qualified Nikon cameras. If all went well, the experiment observed Halley's ultraviolet spectrum from 1200 Angstroms, in the vacuum ultraviolet part of the spectrum, to 3200 Angstroms, just short of the violet end of the visible spectrum. The experiments were built at the University of Colorado and integrated into the Spartan carrier at Goddard Space Flight Center.

After deployment, Spartan-Halley flew thirty to fifty miles from the Shuttle and operated on its own for forty-five hours while it pointed at the comet, ran the cameras, and recorded spectral data. This mission required very little attention from Shuttle astronauts and ended with rendezvous, retrieval, and restow of Spartan.

This year's second Spartan mission is Spartan-3, scheduled for launch on December 15. Carrying an electronographic Schmidt camera similar to designs launched many times aboard sounding rockets, Spartan-3 will take pictures in the deep ultraviolet to record exceedingly hot objects, young stars, and white dwarfs.

The Astro Observatory Missions

Scheduled for launch early this month, the first of the Astro observatory missions will focus on Comet Halley. The timeline for the mission is critical: If it flies a few weeks late, the international fleet of spacecraft heading toward Halley will have already passed the comet by. However, the planned March 6 launch date will place Astro-Halley in the right place at the right time. According to Dr. Burton Edelson of NASA, "The opportunities for science synergism between [Astro-Halley] and the armada of Halley encounter spacecraft are significant."

Although there is no American probe to Comet Halley and the Hubble Space Telescope will not be ready in time for Halley, the United States will still participate in the international scientific assault on the comet from space. From Earth orbit, Astro's three powerful ultraviolet telescopes in the Shuttle cargo bay will monitor Comet Halley as the Russian, European, and Japanese spacecraft fly into it. To obtain pictures of the comet, two white-light, wide-field cameras have been added for the Halley mission.

Payload specialists will control the Astro telescopes in real time, making quick decisions on what observations to take. For the few minutes of each orbit when Halley is visible, Astro will image the comet in ultraviolet light, record its spectrum, and measure its brightness.

The three primary Astro instruments are the HUT, the UIT, and the WUPPE (pronounced hut, wit, and woopee). HUT stands for Hopkins Ultraviolet Telescope. Built at Johns Hopkins University, this 36-inch aperture telescope is the largest of the three in the Astro payload and boasts a primary mirror coated with the element iridium for high ultraviolet reflectivity. The purpose of the HUT is ultraviolet spectroscopy of the far ultraviolet (less than 200 nanometers wavelength) down to the extreme ultraviolet (45 nanometers).

At the prime focus of the telescope is a compact yet powerful spectrograph. By switching filters, the astronomer/payload specialist running the HUT can control whatever wavelength range the instrument is observing. For accurate pointing and guiding on faint celestial objects, a television camera monitors the field and can show stars down to 16th magnitude.

The UIT is Astro's ultraviolet eye, the Ultraviolet Imaging Telescope. This 15-inch f/9 Cassegrain camera covers a ⅔-degree field of view and can record blue stars as faint as 25th magnitude in a half-hour exposure using an image intensifier.

By comparing ultraviolet images of galaxies, stars, clusters, and nebulae with conventional ground-based photography, astronomers will be able to identify unusually hot and luminous stars, bursts of star formation in distant galaxies, and dusty regions of space. Never before have such clear, sharp images been available in

With the cabin of the Shuttle mirrored in his faceplate, an astronaut floats in space. Overleaf: Astronauts James van Hoften (by satellite) and George Nelson repair the Solar Maximum Mission satellite in the aft end of Challenger's payload bay. Photo courtesy of the Threshold Corporation, © Smithsonian Institution/Lockheed Corporation, 1985.

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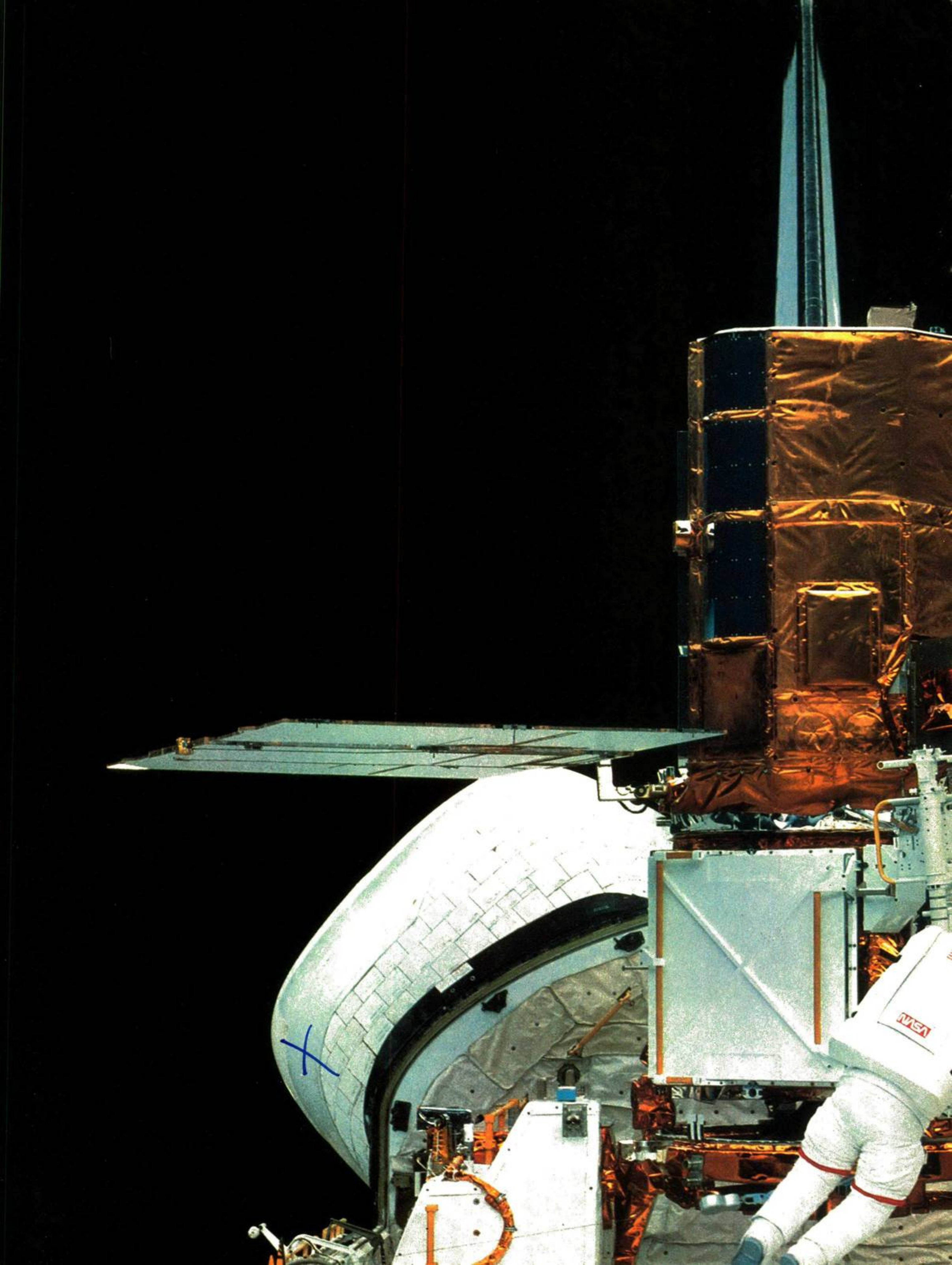

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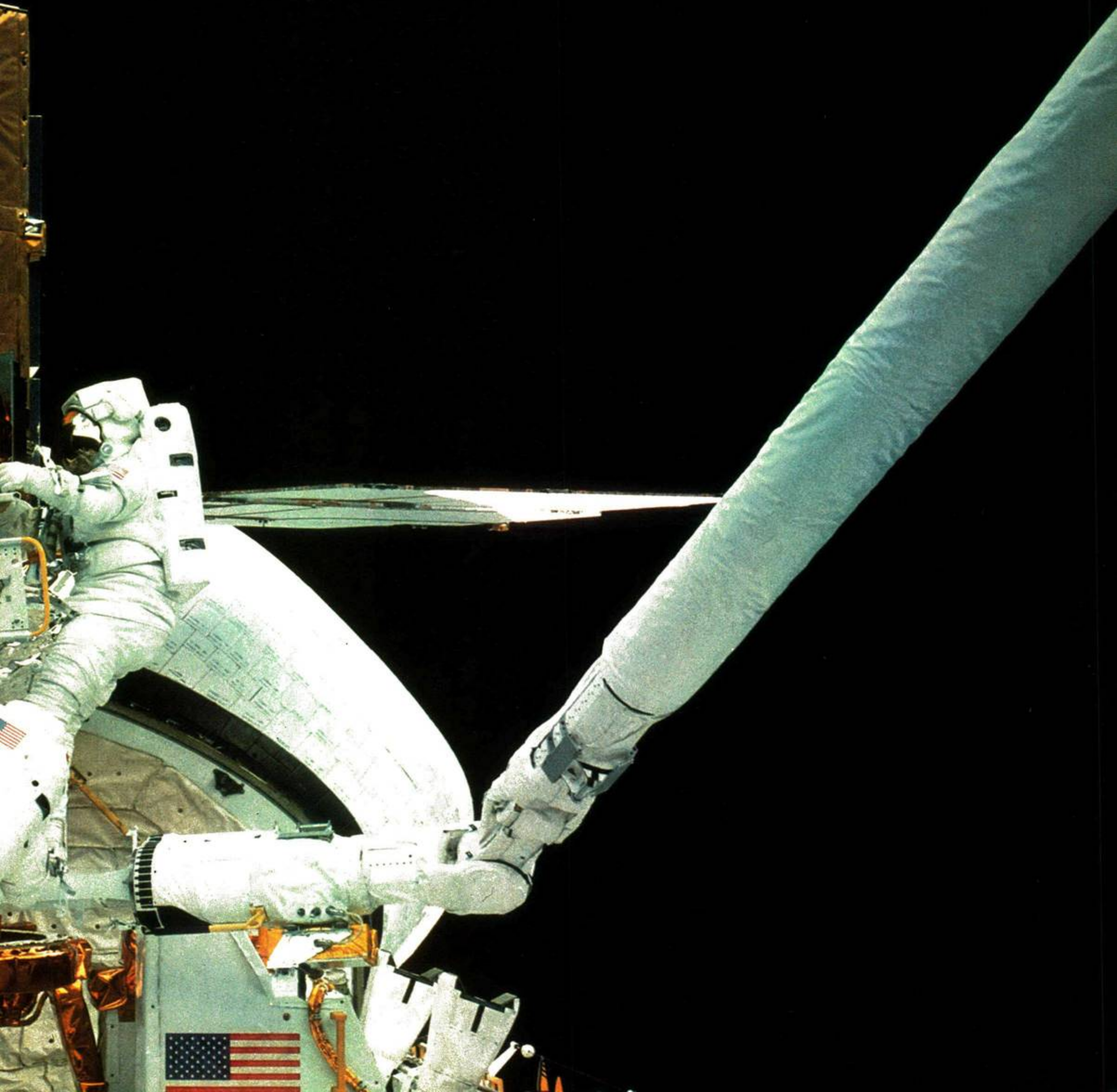


Mission 61-B astronauts pose for the now-traditional group photo. Crew members are (back row from left to right): Jerry Ross, Brewster Shaw, Mary Cleave, Bryan O'Connor, Rudolpho Neri, (front row) Charles Walker, and Sherwood Spring. Ross and Spring worked with the first erectable space structures, EASE and ACCESS, during this flight. All photos not otherwise credited are courtesy of the National Aeronautics and Space Administration.

the ultraviolet so chances are quite high that UIT will also record the unexpected.

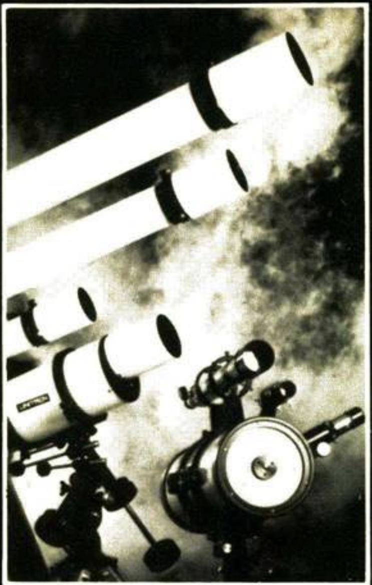
WUPPE stands for Wisconsin Ultraviolet Photo-Polarimetry Experiment. Designed by astronomers at the University of Wisconsin, the WUPPE can simultaneously measure the spectrum, intensity, and polarization of light from stars, galaxies, or quasars down to 16th magnitude. This makes it particularly well suited for learning about dusty regions of space — and comet dust, of course!

It is difficult to forget that many missions, including some that the Space Shuttle will fly this year, were delayed, descoped, or defunded by Shuttle program cost overruns. This year, in particular, it is difficult to forgive the loss of an American probe to Comet Halley that was due, at least in part, to the cost of the Shuttle. Nevertheless, the Space Shuttle is here, it works, and the future of the American space effort now depends on it.

Astronomy will change with the payloads that the Space Shuttle boosts into orbit. Just as the first crude space probes opened our eyes to the Solar System and our vision snapped into sharp focus with the second wave of flybys and orbiters, the coming generation of great observatories in space will open our eyes to the very depths of the universe and bring it into sharp focus. And the Space Shuttle is the launch vehicle, the "space truck" if you will, that will boost those space observatories and solar system probes into orbit.

But we must not forget that the Shuttle is a means to an end, and not the end itself. Likewise, we must not forget that the Space Station can justify itself only insofar as it aids our exploration of the universe. The Space Shuttle was and is an expensive program; the Space Station will be expensive, too. If we build a "truck" and a "gas station" in space but neglect the cargos for the truck to carry and ignore the views we said we wanted to see, there is no point or purpose to our actions.

— *Richard Berry*



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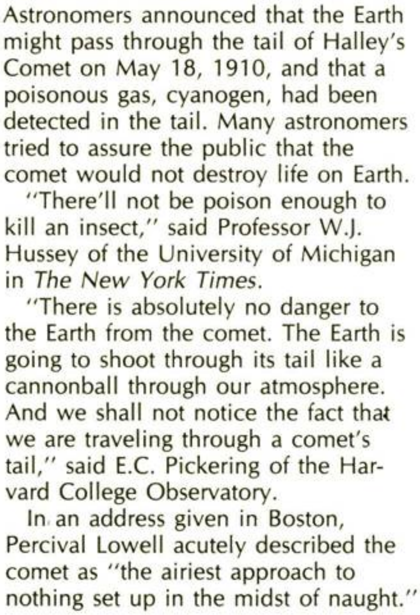
A Halley Scrapbook: What We Did in 1910

POISON GAS SCARE
Astronomers announced that the Earth might pass through the tail of Halley's Comet on May 18, 1910, and that a poisonous gas, cyanogen, had been detected in the tail. Many astronomers tried to assure the public that the comet would not destroy life on Earth.

"There'll not be poison enough to kill an insect," said Professor W.J. Hussey of the University of Michigan in *The New York Times*.

"There is absolutely no danger to the Earth from the comet. The Earth is going to shoot through its tail like a cannonball through our atmosphere. And we shall not notice the fact that we are traveling through a comet's tail," said E.C. Pickering of the Harvard College Observatory.

In an address given in Boston, Percival Lowell acutely described the comet as "the airiest approach to nothing set up in the midst of naught."



FLOUT THE COMET'S TAIL

Astronomers Decry Fear As It Whisks the Earth.

"Aery Nothing Amid Nought," Says Prof Lowell.

PREVENTIVE MEASURES
According to the *Los Angeles Times*, a wire story from Galveston, Texas, indicated that two men sold hundreds of comet pills (at $10 per pill for a concoction of sugar and quinine) and inhalers (costing $2 to $24 each). When the men were arrested for swindling, their clients would not cooperate with the authorities and actually pleaded for their release.

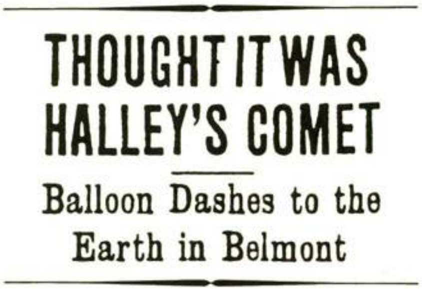
The *Mobile Register* of Alabama noted that many people were eating their cured meats and fruit preserves since they felt they would not need those items after May 18 — the date of Halley's closest approach to Earth. A Denver man paid a debt he had owed for twenty years so that he could "enter eternity with a clean bill."

The *Atlanta Constitution* reported that hundreds refused to work that week since payday came after the fateful day. A family in Columbus, Georgia, planned to wait out the comet in their home with windows and doors locked and the keyholes stopped up to prevent cometary gases from entering. Miners in Indiana, Colorado, and Pennsylvania didn't go to work on May 18.

Articles in the *Chicago Tribune* and the *Milwaukee Journal* reported that physicians were being asked for medicines to ward off the effects of dangerous gases, school children were asking teachers for permission to stay home, and priests and ministers were being asked for words of comfort. Father Brennan of St. Louis wrote a comet poem titled "The Good God Hath Marked Out the Comet's Orbit Place" to reassure the many frightened people who were calling him at all hours of the day and night.

A bizarre incident reportedly occurred near Aline, Oklahoma, where a group of religious fanatics prepared to offer a human sacrifice to save the world from destruction. The sheriff rescued the intended victim, a sixteen-year-old girl, before the ritual began.

IT'S COMET NIGHT!
Wednesday, May 18. Thousands of residents of New York City went to bridges, riverbanks, and hotel rooftops. Milwaukee residents gathered along the lakefront. In many areas, such as Atlanta (where a newspaper story indicated the city would be "saved" by clouds), nothing could be seen due to clouds or fog.



THOUGHT IT WAS HALLEY'S COMET

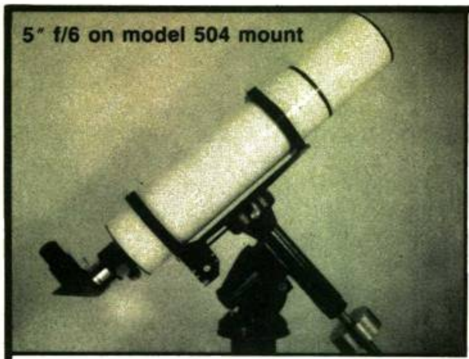
Balloon Dashes to the Earth in Belmont

Readers of the *Milwaukee Journal* were encouraged to take a good sniff of air before they went to bed just in case the tenuous comet tail might have intermingled with the Earth's atmosphere. Other people bottled some of the air that night, hoping to capture gas from the comet.

Pranks abounded. In Atlanta and Philadelphia, participants of comet parties were frightened by the sight of moving, luminous objects that turned out to be burning materials attached to balloons.

Observers who maintained their vigil throughout the night of May 18/19 were surprised to see the comet's tail in the east before sunrise. These included Professors S.A. Mitchell, Edwin Frost, and Edward Barnard at the Yerkes Observatory. Explanations of this effect included possible miscalculations, curvature of the tail (detected earlier by Professor Barnard on May 17), and a sudden change in the length of the tail.

This unexpected view in the east, as well as the apparent lack of a tail when Halley was seen in the west,



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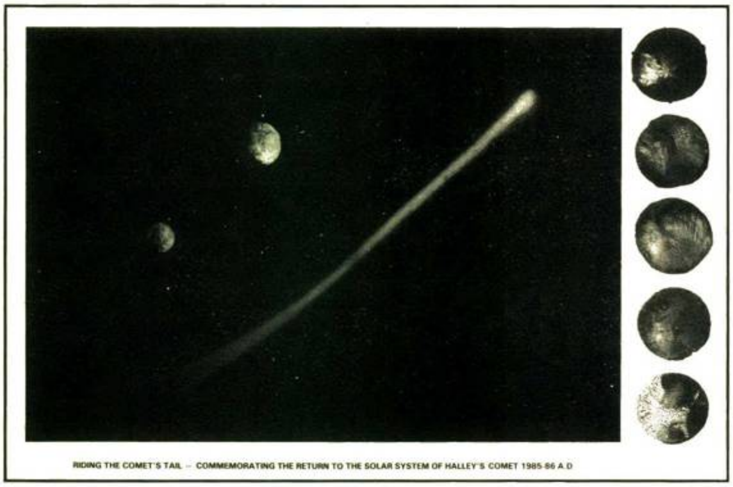
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prompted some newspaper writers to comment on the confusion of the "wise men" who had been studying the comet. Cartoons depicted the comet curving around Earth somewhat like a question mark.

COMET VISIBLE TO NAKED EYE

Traveling Fast but Some Good Photographs Obtained.

VENUS IS NOT HALLEY
An article in the *Valdosta* (Ga.) *Times* on April 18 cautioned readers about assuming that the morning star — Venus — was the comet. Under the headline "Think Venus is a Real Fine Comet," the *Richmond Times-Dispatch* reported Virginians' satisfaction after seeing the bright planet in the east a week before it was first sighted through a 26-inch telescope.

COMET PARTIES
As the comet brightened in the morning sky, a new phenomenon evolved: comet parties. The fad started as a neighborhood activity, but soon large numbers of people congregated at places that offered a good view of the eastern horizon, such as a bridge in Augusta, Georgia, where a crowd of 500 Halley seekers gathered.

Elaborate comet parties, with breakfast and musical entertainment provided, were held on the roofs of hotels in New York City.

According to the *Albany* (Ga.) *Herald*, proper comet-party etiquette would not permit asking an elderly lady if she remembered the last visit of Halley's Comet. In contrast to other social events, however, yawning at a comet party was not considered uncouth.

COMET PROFIT
"Comet Week Sales" were reported on items like furniture, shoes, and seeds. Jacksonville's *Florida Times-Union* ran the picture of a comet passing through the Solar System carrying a banner proclaiming a new soft drink under the headline: "Halley's Comet has been burnt out by constant repetition."

Merchants weren't the only people using the comet to their own advantage. The *New York Times* reported that two young men persuaded residents of Towaco, New Jersey, to climb a nearby mountain in a contest to prepare for the best description of the comet. When the people returned to their homes, they weren't able to find the promoters of the contest — or their chickens, which were missing from their coops.

PUNS ABOUND
Political cartoons showed the head of the comet replaced by that of politicians such as Teddy Roosevelt. Sports page cartoonists drew the comet as a rapidly moving baseball.

Short, witty remarks appeared, especially in editorial columns. The *Dallas Morning News* reported that "The tail of Halley's comet is only 22,000,000 miles long — and that's no tale." As the editor described the gas in the tail of the comet, he asked: "But isn't it possible that a lightning bug was perched on the end of my telescope?"

The *Nashville Tennessean* reported that husbands who wandered about late at night might tell their wives they had been to a comet party. And the *Jackson* (Miss.) *Clarion-Ledger* wrote, "Halley's comet is an early riser, and sprints a million miles before breakfast every day."

The *Boston Globe* commented: "Mr. Halley's comet is now moving through the constellation Pisces, but going at a speed of about 1,800 miles-a-minute it cannot stop to fish," and "Now that Harvard has succeeded in picking up Halley's comet after its re-appearance, Yale has hopes."

Speculation about the comet's diminished tail since its visit in 1835 prompted a writer for the *Savannah Morning News* to suggest: "Possibly [the tail] was afraid or ashamed to measure it[self] against the new hats that are being worn by the dear ladies." The same paper also printed: "A Cornell professor says that the comet is slowly stealing eastward in the constellation Pisces. That sounds fishy."

COMET'S TAIL PLAYS TRICK

Fails to Sweep the Earth, Astronomers Say.

Appears in East When Should Be in the West.

A TRAGIC FATE
Several people reportedly became so concerned about the comet destroying the world that they committed suicide. In Evansville, Indiana, a man who had seen the comet in 1835 died as a result of "exposing" himself to it a second time.

Some people allegedly went insane. One of the most widely circulated reports described a man near San Bernardino, California, who believed the end of the world was near and attempted to crucify himself.

SEE THE "MONSTER SWORD"
The comet became much brighter in the morning sky during early May. The *San Francisco Examiner* estimated that 10,000 people gathered on hills surrounding the city at 3:00 a.m on May 13 to see the comet. Father Brennan, an astronomer and priest, encouraged readers of the *St. Louis Post-Dispatch* to see the gorgeous spectacle, which looked like a "monster sword suspended in the sky." Hundreds of people responded. The *Post-Dispatch* noted that no two people, however, described the comet in the same manner.

HALLEY'S COMET NOT TO BLAME

For the Gloomy Days, Says Mr Smith.

Weather Expert Now Promises

AND A LUNAR ECLIPSE, TOO!
Weather conditions had prevented many people from viewing the comet on May 18 and 19. Dean Herbert A. Howe of Denver University suggested that a good time to view the comet would be during the total lunar eclipse on Monday, May 23. Unfortunately, he overslept on the 23rd because he was exhausted from weeks of rising early.

But many people across the country did see the comet at that time. An estimated 1,500 people saw the eclipse and the comet from Mt. Tamalpais, north of San Francisco, and President Taft himself viewed the comet from the U.S. Naval Observatory.

"FAREWELL OLD HALLY"
An article in the *Macon* (Ga.) *Telegraph* summarized many peoples' feelings toward Halley: "The comet . . . was with us strong last night [May 27], but it is feared that the effulgence is merely the big flicker before the light goes out. Last night . . . his tail was a thing of mellow misty glory and his bright and gleaming head seemed to carry with it an arrogant contempt for those mere ordinary heavenly bodies drearily tied to their constellations and swirling around in chafing orbit . . . . The comet is going. It can be seen tonight and tomorrow night — after that it will be pretty dim and in a day or two will be on its long 75-year jaunt. Farewell old Hally . . . . "

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When Comet Twain Reached Perihelion

Samuel Langhorne Clemens, better known as Mark Twain, the dean of American humorists, was born when Halley's Comet appeared in 1835 and died when it reappeared in 1910. His lifetime closely corresponded to the "long year" of the great comet. The difference was just thirteen days.

Twain developed a compelling fascination with the apparition that preceded his arrival. To him it became an omen mystically bound with his own span from birth to death. This bond was reinforced by a succession of spectacular comets that were visible during his lifetime: the Great Comet of 1843, Donati's Comet of 1848, Tebbutt's Comet of 1861, the Great Comet of 1862, Coggia's Comet of 1874, and the Great Comet of 1881.

Twain's fascination with comets wove its way into the plots of two of his works: *Captain Stormfield's Visit to Heaven* and *The Mysterious Stranger*. The first work, written when Twain was 33 years old, was a satire on conventional notions about heaven and religion. The story opens with Captain Stormfield's entry through the gates of heaven. He tells a gentleman named Peters about his adventures en route:

"Well, when I had been dead about thirty years, I begun to get a little anxious. Mind you, I had been whizzing through space all that time like a comet. *Like* a comet!

"Why, Peters, I laid over the lot of them. Of course there warn't any of them going my way as a steady thing, you know, because they travel in a long circle like the loop of a lasso, whereas I was pointed as straight as a dart for the hereafter; but I happened on one every now and then that was going my way for an hour or so, and then we had a bit of a brush together. But it was generally pretty one-sided, because I sailed by them the same as if they were standing still. An ordinary comet don't make more than about 200,000 miles a minute.

"Of course when I came across one of that sort — like Encke's and Halley's comets, for instance — it warn't anything but just a flash and a vanish, you see. You couldn't rightly call it a race. It was as if the comet was a gravel-train and I was a telegraph despatch."

The Stormfield story was written in 1868 but remained unpublished for more than forty years because Twain felt his irreverent views would shock his readers. It was finally published in 1909, one year before the return of Halley's Comet. Reaction by a then more sophisticated public was not outrage but a mere ripple of amusement.

By 1909, the aged humorist had partly finished three versions of *The Mysterious Stranger*, a fantasy in which Twain expresses his bitter views on life and religion using the Devil as an intruder into human affairs. In one version of the manuscript, the Devil comes to Twain's boyhood home of Hannibal, Missouri.

"How do you know when a comet has swum into your system?" the Devil asks. "Merely by your eye or your telescope. But I, I hear a brilliant far stream of sound come winding through the firmament of majestic sound and I know the stranger is there without looking."

Was Twain expressing his mysticism about the comet that had tarried for so long among the orbits of the outer planets but was now streaming toward a rendezvous with the Earth and Sun?

In June 1909, Albert Bigelow Paine, Twain's secretary and biographer, visited the author and found him examining several sheets of paper covered with numbers. Twain loved to contemplate the immensity of space and had calculated the number of miles between the Sun and the star Alpha Centauri. Proudly he showed Paine his results. During their subsequent conversation on astronomy, the humorist made an extraordinary prediction.

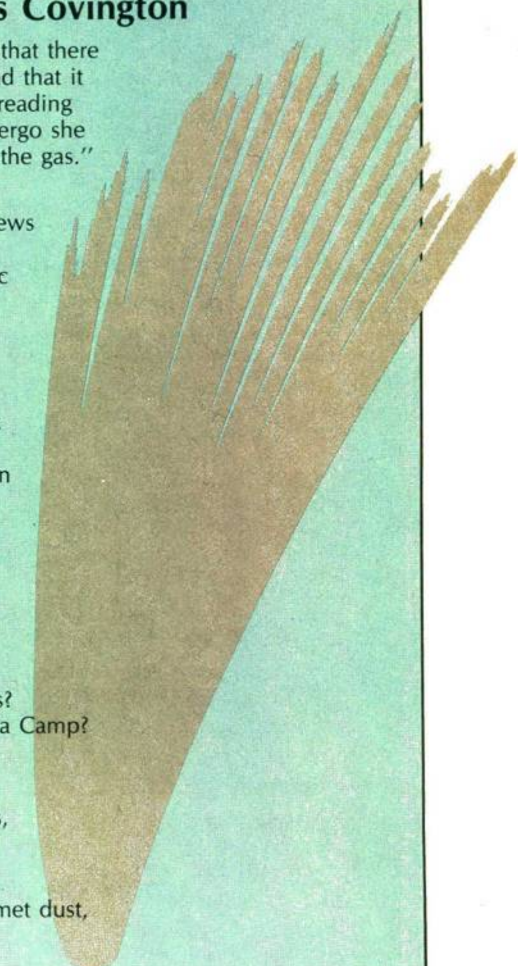
"I came in with Halley's comet in 1835," said Twain. "It is coming again next year, and I expect to go out with it. It will be the greatest disappointment of my life if I don't go out with Halley's comet. The Almighty has said, no doubt, 'Now here are two demonstrable freaks; they came in together, they must go out together.' Oh, I am looking forward to that."

Halley's Comet swung past perihelion on April 20, 1910, and weighed anchor, as it were, for the great outward-bound voyage.

Mark Twain — Captain Stormfield — joined it the following day.

Kenneth Weitzenhoffer
Brooklyn, NY

Elegy for Miss Covington



"Blanche Covington made up her mind that there
was no escape from [Halley's] Comet and that it
would kill everyone in Chicago . . . . Dreading
the suffering that she might have to undergo she
locked herself in a room and turned on the gas."
The New York Times, May 18, 1910.

Miss Covington had read the dreadful news
about the gas.
The Comet's tail contained — a scientific
fact — cyanogen.
Identified by almond scent, a particle
upon the tongue could kill,
the papers said.

Miss Covington could see a future bleak
as outer space;
closed door and window, then turned on
the gas — illuminating —
and took her first breath of eternity.
A neighbor called police;
Miss Covington was saved.

The New York Times does not record
her further life, or death.
Had she a brother in the War
who came back maimed by mustard gas?
A favorite niece in Europe, deported to a Camp?

Likely she just lived on, to die
of peaceful age,
using her gas range for the family meals,
a wholesome loaf of bread.

Miss Covington, stay well!
Your molecules waft by, mixed into comet dust,
trailing the faint familiar smell
of home-baked almond cookies.

Barbara Goldowsky
Southampton, NY

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- Richard Berry, Editor-in-Chief, *Astronomy*, Dec.'85, 'Reviews'.

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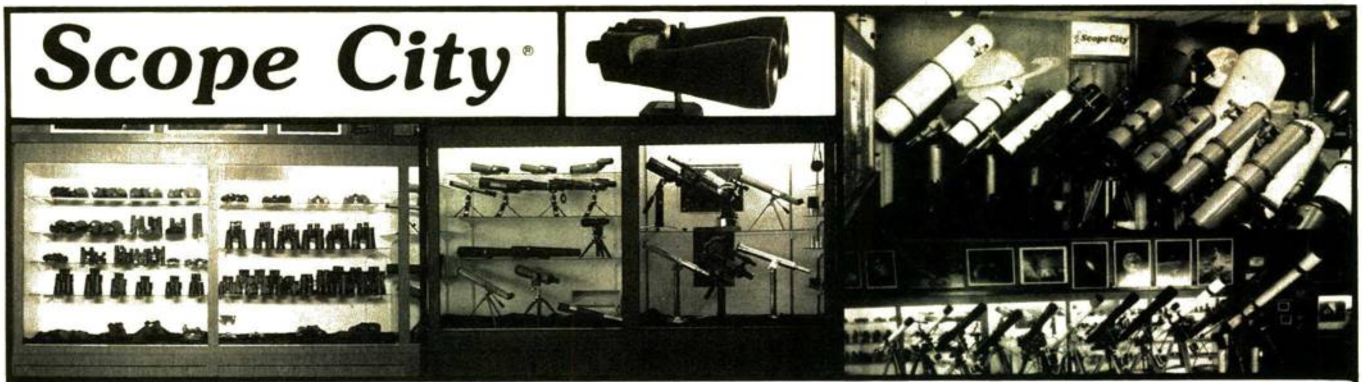

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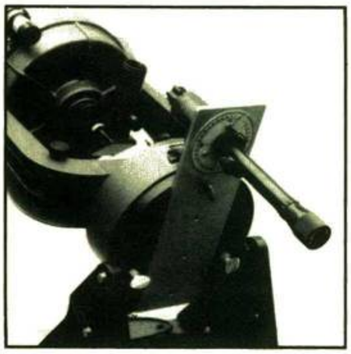

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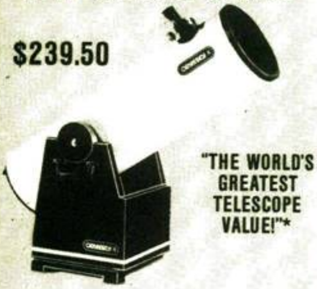

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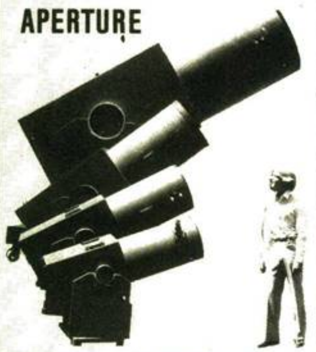

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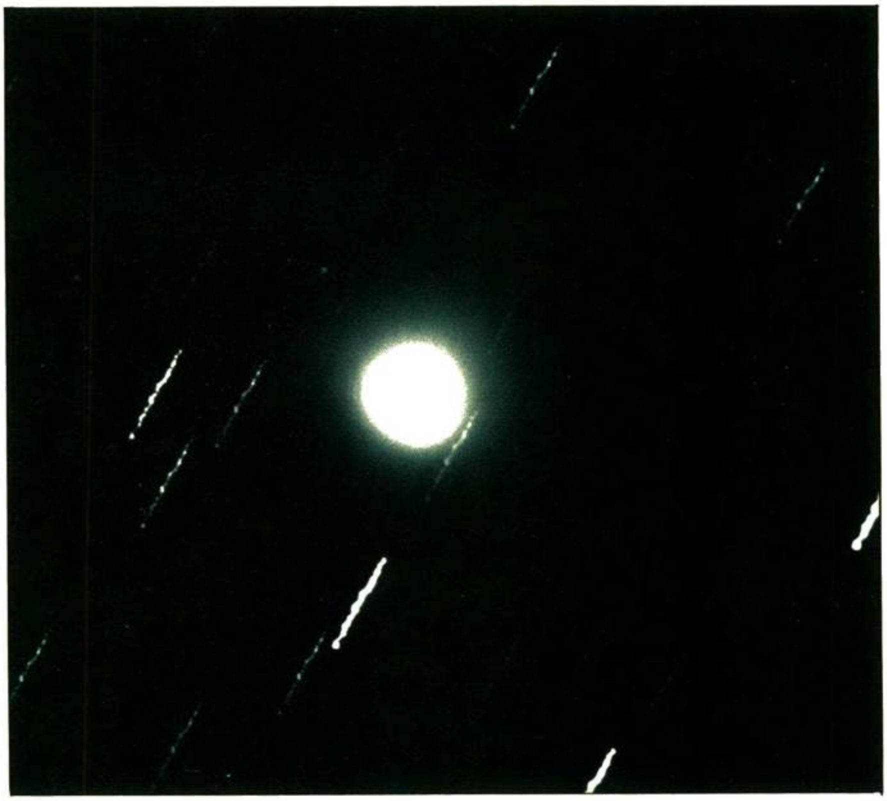
Astronomy 3/86

Halley's Comet Passes the Pleiades

During the middle of November a curious celestial event happened. Fortunately, skies were clear over a large part of North America and many thousands of observers were able to see it. On November 16, 17, and 18, Halley's Comet — that visitor from the deep frozen wastes of the outer Solar System — passed within 4° of the Pleiades star cluster, one of the brightest and most easily recognized landmarks in the sky. The close encounter between comet and star cluster attracted hundreds of backyard sky photographers, many of whom sent ASTRONOMY their black-and-white or color photos of the passage. A selection of them is reproduced in these pages.

Halley's Comet surprised astronomers during November and early December by continuing its sharp increase in brightness. In August, when the comet reappeared from behind the Sun, it shone at a disappointing 16th magnitude. By September, Halley had brightened to 13th magnitude and was visible as a fuzzy "star" in large backyard telescopes. In mid-October, the comet shone at a mere 11th magnitude and was a few arc-minutes across, but then it began a leap in size and brightness that has continued up until press time. By the first week of December, it had jumped to 5th magnitude and was nearly half the diameter of the Full Moon.

So Halley may become a reasonably bright naked-eye comet — contrary to most predictions — with a nucleus as bright as 2nd magnitude and a tail several degrees long. By early March, astronomers will have a pretty good idea of how the comet will appear during March and April when Halley will be at its brightest.

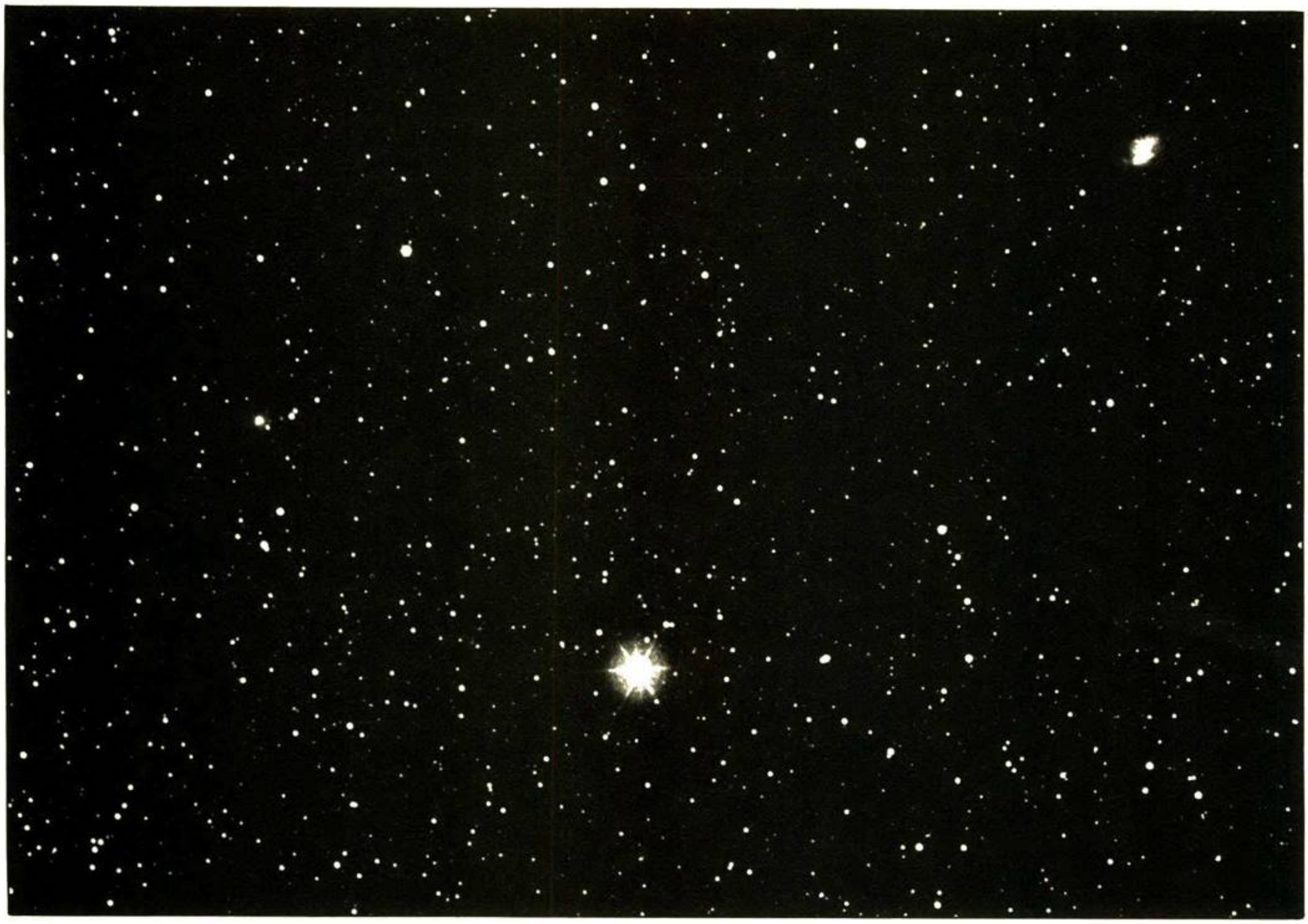


On November 17, Jack Newton photographed Comet Halley by guiding his telescope on its nucleus. The result shows an asymmetrical halo of faint gas centered on the dazzlingly bright inner coma. Newton used a 20-inch f/5 reflector, Tech Pan film, and a 20-minute exposure.

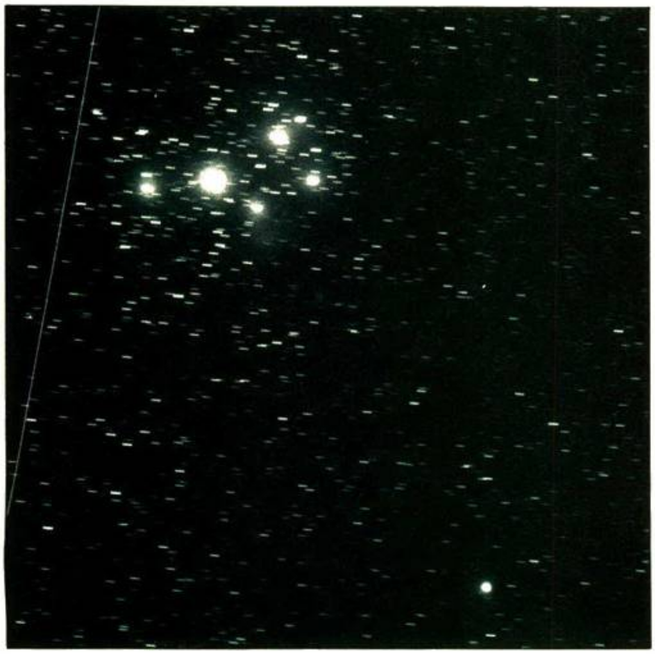
As Halley passed directly south of the Pleiades on November 15, Mace Hooley made three exposures lasting 15 minutes each and combined them to show the comet's motion over 30 minutes. He used an 8-inch f/1.5 Schmidt camera and Fujichrome 100 film.

At the time of this writing, however, we know about Halley's behavior only up to the first week of December. Reports from November have been extremely encouraging. On November 7, for example, Alan Goldstein and a group of observers from the Louisville Astronomical Society viewed the comet from Floyd's Fork Park outside of Louisville, Kentucky. The sky was moderately dark, but Halley was not visible to the naked eye. The group used 7x50 and 10x50 binoculars to spot the comet, which in Goldstein's words appeared "like a giant unresolved globular cluster, a low surface brightness glow about the same size as M-55 in Sagittarius but not as concentrated toward the center." Using a 10-inch f/5.6 telescope, the Louisville group saw Halley again on November 9. It then appeared circular with a uniformly bright coma and a condensed, nearly stellar spot in the coma's center. On November 16, they sighted the comet as it approached the Pleiades and described it as appearing basically the same as on the 9th, only slightly brighter.

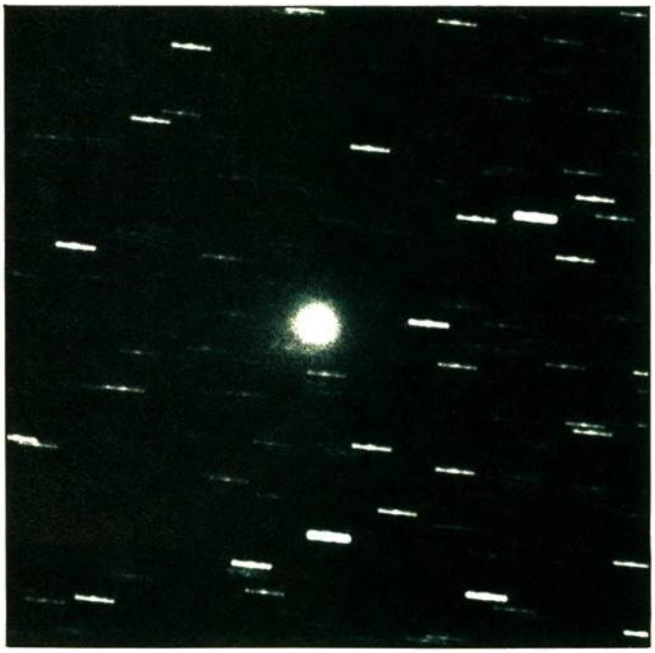
On November 9, two experienced comet observers — Steve Edberg and Charles Morris — made the first naked-eye sighting of Halley's Comet since 1910. They went to a 7,000-foot-high observing



As October closed and observers realized Halley was rapidly brightening, it performed a neat celestial trick by passing in between the bright star Zeta (ζ) Tauri and the famed Crab Nebula (upper right). Just before the passage on October 27, Rick Dilsizian photographed the three objects together in one film frame. He used an 8-inch f/1.5 Schmidt camera, hypersensitized Tech Pan film, and a 3-minute exposure.



Overtaking the Pleiades on its fast-paced trip across the sky, Halley shone at around magnitude 5.5 on November 16 and was growing ever larger. Alfred Lilge guided on the comet to create a wide-field view (left). He used a 6.9-inch f/3.5 lens and red filter, 098-04 film, and a 30-minute exposure. An extreme enlargement of the section containing Halley (right) shows faint arcs of material streaming off the comet's nuclear area.



Just two days before Halley's close encounter with the Pleiades, Eugene Brings made this close-up photo of the comet. He guided on the stars causing the comet to smear out, and used an 8-inch f/5 SCT, hypersensitized Fujichrome 100 film, and a 20-minute exposure.

At closest approach on November 15 and 16, Comet Halley appeared 4° southeast of the Pleiades cluster's center. Jim Riffle recorded the scene on the 15th with a 12-inch f/5 Astro Mak, 103a-E film, and a 30-minute exposure.

site in southern California. Knowing that the comet shone at about 7th magnitude, they looked very carefully and spied it as a tiny fuzzy glow. Edberg and Morris knew they had found Halley because the surrounding area contained no faint clumps of stars that might be confused with the diffuse glow of a comet. After almost seventy-five years, human beings had seen Halley's Comet without optical aid.

As Halley rapidly brightened, Edberg and Morris' sighting was followed by more naked-eye sightings. On November 14, Jack Marling, who was observing planetary nebulae from an observatory at Digger Pines, California, saw Halley as a threshold naked-eye "out-of-focus star." It was "easy to see — even bright — in finderscopes and binoculars." On November 17, Richard Berry and I detected it without optical aid from Harrington Beach State Park, 35 miles north of Milwaukee. The comet appeared as a small diffuse glow several degrees southeast of the Pleiades and was visible only with averted vision. Also on the 17th, Glenn Chaple, observing from a slightly light-polluted backyard in Townsend, Massachusetts, easily spotted Halley in a 3-inch telescope and binoculars but couldn't see it with eyes alone. In the 3-inch scope it appeared as a small hazy cloud of light with a slight central condensation.

David Healy, a veteran astrophotographer and observer, proved that Halley was visible from a suburban observing site on November 18. That night he spotted the comet from his backyard in Manhasset, New York — just 20 miles from New York City. Because of the bright sky, Healy had to use the setting circles on his 8-inch f/10 SCT to zero in on Halley. After polar aligning the telescope he dialed in the coordinates and saw a "fuzzy condensed blob" at low power. Healy knew that blob had to be the comet. Once he knew the comet's exact position, he located the tiny patch of fuzz with a pair of 10x70 binoculars in the same light-polluted sky.

Particularly thrilling for Healy was his mother Marjorie's sighting of the comet from rural New Hampshire. She had viewed Halley as a four-year-old girl from suburban Boston in 1910 and had taught David about the stars when he was a little boy. At age 80, Marjorie Dow Healy is one of a relatively small number of individuals who have viewed Halley during two separate apparitions.

By late November, Halley's Comet had passed by the Pleiades and grown brighter and larger; most reports placed it at 5th magnitude and half a degree across. A tail, as such, wasn't visible; from our viewpoint, the tail lay behind the coma but hints of it appeared as a general asymmetrical glow on the comet's western side. A medium-sized telescope showed a fan of nebulosity wrapping around the nucleus and stretching outward on either side. Professional astronomers equipped with large telescopes and CCD cameras began to detect jets of material sputtering out from the nucleus. Halley was becoming a full-fledged, detailed comet.

On November 22, in spite of the Moon lying close by in the sky, Brian Skiff saw Halley's Comet at Lowell Observatory with a 21-inch photometric telescope. He used the previewer eyepiece placed ahead of the path of the photometer to visually inspect Halley at high power. Because the Moon lay close, Skiff didn't see much detail: "Halley appeared very bright, definitely asymmetric, and much dimmer on its eastern side. Normally when the Moon's out of the sky it's a very easy naked-eye blob seen from Mars Hill."

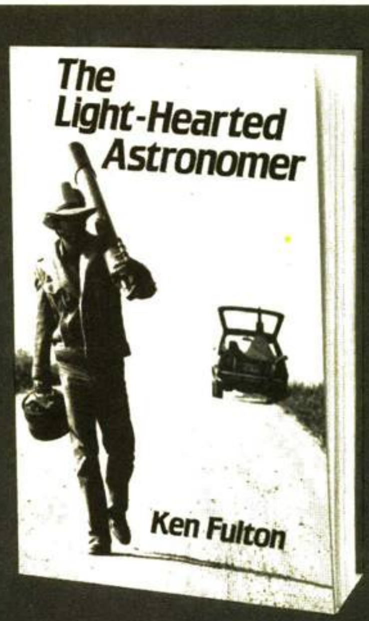
Also on the 22nd, astrophotographer Ben Mayer of Los Angeles made several exposures of Halley and was surprised at how fast it traveled across the sky: "It moved about one comet diameter per hour. I took successive exposures of it once every hour and got the same comet in a completely different field of stars!"

David H. Levy, an observer working for the International Halley Watch, observed Halley during a break in the clouds that were hanging over Tucson on Thanksgiving Day, November 28. Levy works with the 20-inch Cassegrain telescope at Tumamoc Observatory near Tucson, which is fitted with a CCD camera. Levy and University of Arizona astronomer Steven M. Larson are looking for jets emanating from Halley's nucleus and for other activity using the sensitive CCD imaging system. After eating Thanksgiving dinner, Levy stepped outside and was startled to see a clear sky. He hurried to the observatory, set up the camera, and took ten images of Halley's Comet before clouds rolled back in.

On the video monitor attached to the CCD camera, Levy saw something he couldn't quite believe: two jets, one 10 arc-seconds long and another 7.5 arc-seconds long, coming out from the nucleus. The comet filled the monitor's screen and was "a large, asymmetrical oval with a bright, condensed nuclear area. The comet appeared as a delicate filamentary object that was changing before our eyes."

Since Halley's Comet had turned around so completely from its dim showing in August and September, Levy summarized many observers' feelings well when he said of that night: "I wouldn't exchange this apparition with 1910's for anything. This time we're seeing Halley as it's brightening. We're seeing it build itself into a real comet."

— David J. Eicher



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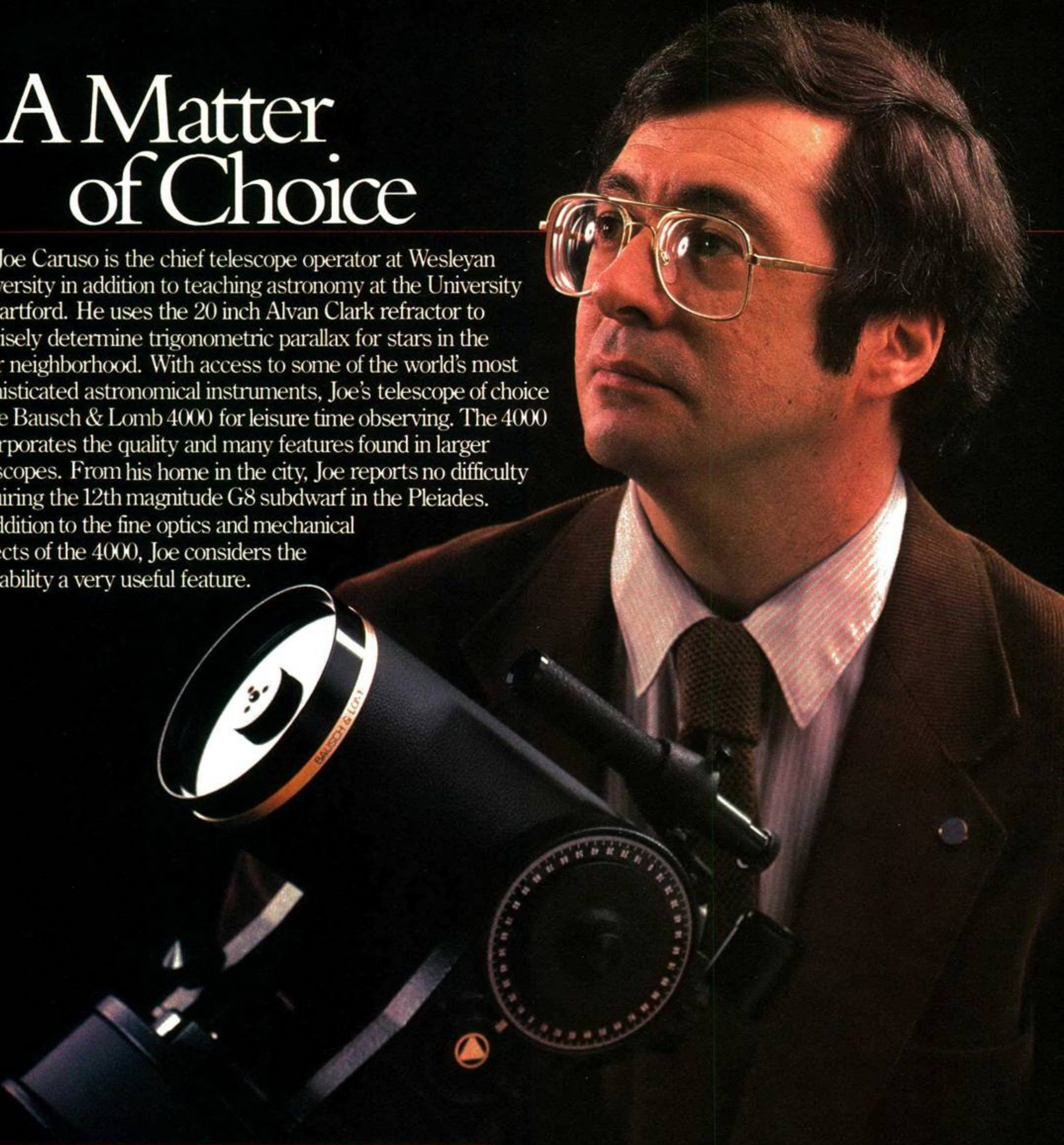
A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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ASTRONOMY
In Focus

Twice In A Lifetime

Sir / My mother was a school teacher in Essex, England during the late 1880s. Because of her educational background, when Halley's Comet made its 1910 apparition she insisted that my father take me to a suitable spot to observe the phenomenon. Born on Halley's 249th birthdate — November 8th, 1905 — I was not yet five years old at the time, but I have always retained a clear recollection of the spectacle.

The comet itself was about one-quarter of the Moon's diameter in size; there was no color other than usual "star-color" (but not sparkling) and the tail was about the diameter of the Moon in length.

In 1835 nobody claimed to have seen Halley's in 1759, and, so far as can be ascertained, in 1910 nobody claimed to have seen the 1835 apparition. An Australian television program this year stated that ". . . nobody on Earth has ever seen Halley's on two apparitions."

It follows, therefore, that the *first* of "us over eighty-year-olds" (or ninety-year-olds) who saw Halley's in 1910 and spot it *this visit* will go into the record books as "the first on Earth."

I hereby claim that title. Here in Caloundra at midnight Eastern Standard Time (14.00 hours universal time) on November 13th, 1985, I located Halley's Comet through binoculars on a line from Mintaka (Orion's Belt) through Epsilon (which, with Aldeberan, forms the base of the triangle in Taurus known as the Hyades).

Two nights later, I again viewed the comet in an astronomical telescope at our local observatory; the following night, Saturday the 16th, the local astronomical society staged a public sighting on top of the nearby Blackall Range where we all viewed the comet through five different telescopes.

In 1910, my family lived in Mount Morgan — a mining town just a few miles south of the Tropic of Capricorn in central Queensland. In April when Halley's is at its best, I intend to motor the 360 miles to make a second viewing from the same spot.

Ted Pelin
Caloundra, Queensland, Australia

Mare Orientale . . . and More

Sir / Thanks for the article on Mare Orientale (Gazer's Gazette, November 1985). Because of it I was able to view the "Eastern Sea" live for the first time, and it really rekindled my interest in astronomy.

The Mare stood out well as a black banana shape and the ring mountains were clearly visible around it; the entire sea was evident with a clearly defined band of "shoreline" in the background.

An additional note to your light pollution article in the same issue: The high cost of energy and tight city budgets have been a blessing in disguise. In the last three years Lubbock has turned out many of its streetlights, causing a marked improvement in viewing from our city. Deep-sky observation is still poor, but you can now see the Milky Way and many more stars than when I first moved here.

Fred L. Redburn
Lubbock, TX

Halley: A Fraud in 1910

Sir / I have researched the 1910 apparition of Halley's Comet as seen from southern England and must agree with Daniel Fischer's comments on light pollution and the generally poor weather there at that time (In Focus, November 1985).

The Evening News, a local English newspaper in Portsmouth, quoted Annie M.H. Sturdee, a local amateur astronomer, in its May 23, 1910 issue. She warned: "Amateur observers will do well to keep as far away as possible from the electric lights, which are not helpful to star gazers." Even more dispiriting, however, was the weather which caused a reporter to write tartly on May 26: "After much watching and the exercise of the patience of Job, Portsmouth has at last seen the comet . . . . Nothing more than an insignificant starry smudge in the western sky to which those whose enthusiasm was not altogether damped [sic] cheerily added a tail. To those who had seen the Daylight Comet, Halley's was a fraud, a delusion, and a snare . . . ." I fear some may share the same view during this apparition, too.

Incidentally, my research has led me to conclude that the overwhelming majority of people who remember seeing a comet in 1910 are actually remembering the January or Daylight Comet and not Mr. Halley's.

H.J.P. Arnold
Managing Director
Space Frontiers Limited
Hampshire, England

Armchair Observers Stand Up

Sir / In response to Jonathan Dolby's scathing attack on my article "The Armchair Observer" (Forum, April 1985), amateur astronomers from across the country wrote to tell me of similar experiences and views on astronomy. Indeed, the lack of negative public response can only mean that more amateurs than care to admit it have fallen prey to the art of armchair observing and have traded their telescopes for a copy of *Burnham's Celestial Handbook*.

We have been blessed with a field of interest as diverse as the universe itself, one which can comfortably encompass both active field observers and those like myself who choose to delve into the theoretical aspects of the science. Dolby writes of the "what ifs" of Galileo, Newton, et al., and their contributions to astronomy. One can counter with the likes of Einstein, Hawking, and a host of others who, although they never gazed through a telescope, have made modern cosmology what it is today. There is no finer scientific instrument than the mind itself.

Today I find myself in the fortunate circumstance of an early retirement with a substantial pension and have decided to fulfill my lifelong dream of becoming a professional astronomer. When growing up in the 50s, I was discouraged from pursuing this "dead-end" field by teachers and counselors alike. The road ahead is long and hard, but it's worth the journey.

Richard Bienkowski
Mt. Sinai, NY

Sir / After reading Mr. Dolby's letter in which he attacks armchair astronomers (In Focus, October 1985), the more I thought about it, the more disturbed I felt by his attitude. He writes that "Astronomy is for tough, dedicated people and if a person can't take the cold, the bugs, and operating the equipment" then they should "get out." Did I miss something? When was Jonathan D. Dolby elected Judge of Astronomical Worthiness?

I think the one true thing that can be said about those who call themselves "amateur astronomers" is that they all got into this because of a love of the stars and planets that fill the night sky. To criticize the likes of Richard Bienkowski for enjoying the wonders of the universe with books and magazines rather than with a telescope is both petty and narrow-minded. This sort of attitude is disturbing enough in our day-to-day lives, but to see it turn up in ASTRONOMY is very sad.

Gary Seronik
Vancouver, B.C., Canada

Speaking Out On Light Pollution

Sir / Thank you for the article on light pollution (November 1985). Because of Halley's Comet, I suspect that people who are normally unaware of this problem are experiencing a raising of consciousness!

The light pollution problem has reached intolerable levels. Not only does it rob us of our right to enjoy the wonders of the sky, but it also represents a waste of our financial and ecological resources. In fact, one can notice a delay in leaf abscission in urban areas relative to rural ones during autumn and a premature leafing in the spring. These are the visible manifestations. I suspect that plants (such as maple trees) are losing their hardiness and ability to withstand environmental stress, meaning an increased probability that they can fall prey to acid rain or other man-made pollutants.

So far studies are lacking in making the various interdependencies known, but I am confident that in the near future the role of light pollution as a major "environmental load" will be clearly established.

I am ready to fight!

Daniel Kahraman
Wheatley, Ontario, Canada

Uranus Rebuttal

Sir / I'm sure I speak for many other right-thinking Americans when I say that proper names like Butz (In Focus, January 1986) — no matter how you pronounce them — are more than a little disgusting.

I'm the father of elementary school children and it makes me queasy when I think of my children having to repeat smutty surnames every time they address their teacher. You smart-guy parents think you have to name all of your progeny after yourselves.

Fiddle-faddle, I say. Let's give our teachers good, clean, wholesome names like Smith or Cheng and keep our school system smut-free!

Darcy C. Deeks
Napa, CA

Ooops!

The photos of Comets Halley and Giacobini-Zinner that appeared in the January issue on page 78 were taken by a team of astronomers led by Jet Propulsion Laboratory planetary scientist Eleanor Helin. The team used the 18-inch Schmidt camera at Palomar Observatory, which is operated by the California Institute of Techology. The work was funded under an asteroid-search program supported by the National Aeronautics and Space Administration's Office of Space Science and Applications.

Behind the Scenes

Getting a Look at Halley

Many ASTRONOMY readers will be preparing to depart for the Southern Hemisphere this month to view Comet Halley. On behalf of all of us here at ASTRONOMY, I'd like to wish you (just a bit enviously!) the best of luck and clear skies. Our staff is planning to stay here in the Northern Hemisphere to handle the big job of producing your magazine. (I've heard New Zealand is beautiful. You wouldn't mind if we just skipped the June issue, would you?)

We know we're not the only people who won't be going south. For those of you who aren't going, we have devoted this month's Gazer's Gazette to the observing prospects for Comet Halley as it appears to Northern Hemisphere observers. As you will see from the article, prospects are pretty reasonable for 32° north latitude but fairly miserable at 42°. If you're *not* planning a quick trip to Peru, Australia, or the Caribbean, the high deserts of the American Southwest should be a suitable destination for a poor man's Halley expedition.

Also in this issue, comet observer Charles Capen provides a few tips on using color filters in comet observing. In Stellar Frontiers, Humberto Campins and Jack Lynch tell how two of NASA's flying observatories will be observing the comet this month. Our feature covers two Shuttle flights that will be devoted to the comet. And, ruminating about Halley one orbit back, our Forum department examines some of the wacky things people said and did in 1910. (But what will they be saying about us seventy-six years from now?)

Our Comet Halley coverage will continue in future issues as more pictures and reports come in from amateur observers around the world. We're pleased at the quantity and quality of what you've been sending in so far. For what it's worth, amateur astronomers sent us the first really good pictures of Halley after it formed a tail. Of course, you can't compete with the 48-inch Schmidt — or can you? So please keep the pictures and reports coming; we'll find or make space for as many as we can.

For you lucky people who are going south of the equator this spring, I'd just like to remind you that we'd be interested in seeing — and publishing — your best Halley photos.

Sincerely,

Richard A Berry

Richard Berry
Editor-in-Chief

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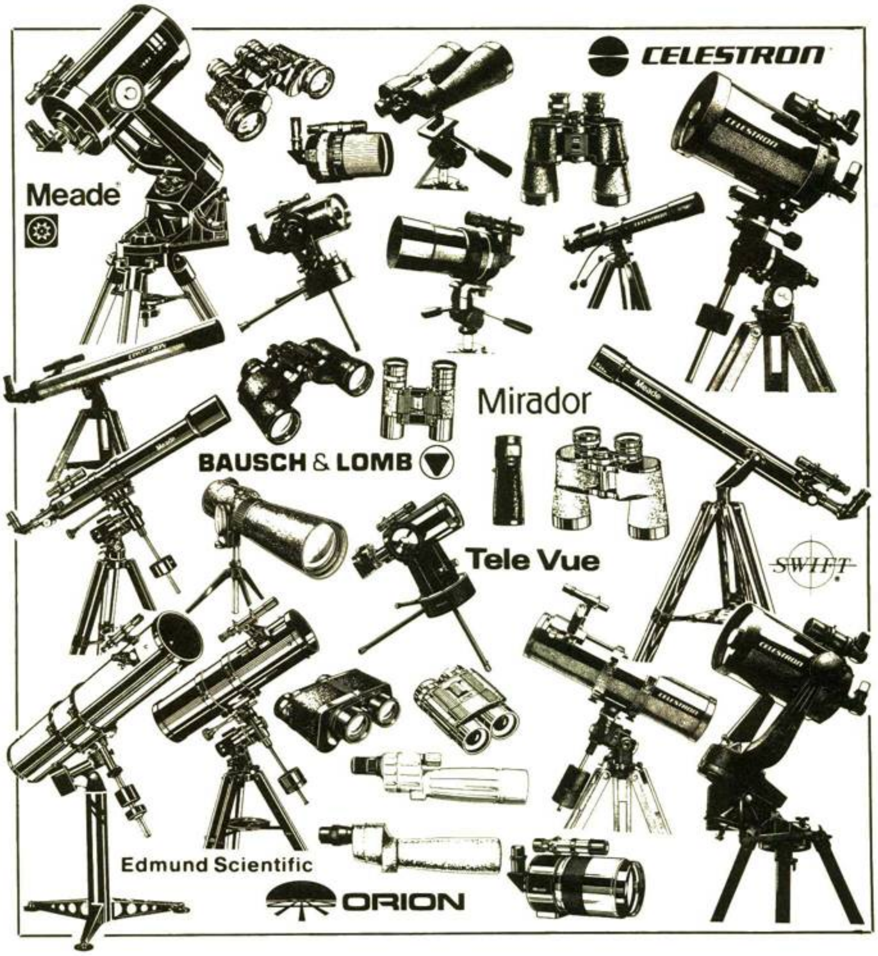

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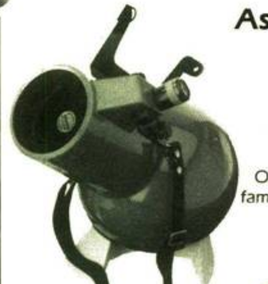

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Gazer's Gazette

Halley At Its Best

Springtime, 1986! The words bring a magical ring to the ears of backyard stargazers everywhere, for they mean not only the familiar return of warmer observing weather but also the arrival of *The Event*. I can still hear a friend's echoing anticipation: "This is our turn; we finally get to see it. *This is it*!" It, of course, is Halley's Comet.

If you haven't yet seen Halley, now is the time. When the comet was at its closest point to the Sun during February (it reached perihelion on the 9th), Halley rose and set with the Sun and couldn't be observed. In March and April, on the other hand, the comet is at its best and will provide the brightest and largest spectacle it can muster for this visit.

Throughout March the comet will lie in the early morning sky, but during April it will sweep low across the southern sky and become an evening object. Then from the beginning of May through June, Halley will rapidly dim as it moves out toward its farthest point from the Sun, which it will reach early in 2024. It won't brighten our skies again until the year 2061. The message is clear: get out under the stars this March and April and see as much of the comet as you can while you still can!

Hopes for Halley

For several years we've heard chatter about this apparition being less than ideal, and reports from recent months as well as last-minute information have been hardly more encouraging. During August and September 1985 when observers with large backyard telescopes first sighted Halley, the comet was disappointingly dim. By mid-October, though, Halley had surged in brightness, raising hopes that it would indeed be a bright, easy, naked-eye comet. November saw Halley accelerate across the sky, pass the Pleiades cluster in Taurus, and become easy to spot in binoculars. The comet's visibility improved throughout December, brightening to magnitude 4.5 and developing a faint tail some 3° long. In late December, professional astronomers photographed an extremely faint tail 10° long.

Jim Riffle

Even after observing the comet's behavior for some months, it's still quite difficult to predict exactly what Halley will look like at its brightest. "Comets are damned unpredictable creatures," muses Steve Edberg of the International Halley Watch.

What we *can* predict accurately, however, is Halley's position in the sky. During March, Halley's Comet will move slowly westward through the constellations Capricornus and Sagittarius with its head passing just beneath the latter constellation's Teapot asterism. April will see Halley accelerate westward as it travels through the tail of Scorpius and continues through Lupus and Centaurus. On the evening of the 15th, the comet will pass right by the bright galaxy NGC-5128. All this adds up to good news for Southern Hemisphere viewers who should have no problem whatsoever spotting the bright comet high up in the sky. But for many Northern Hemisphere observers (including those in Europe, Japan, and most of the United States), Halley's rather low elevation in the sky will be, at the very least, discouraging.

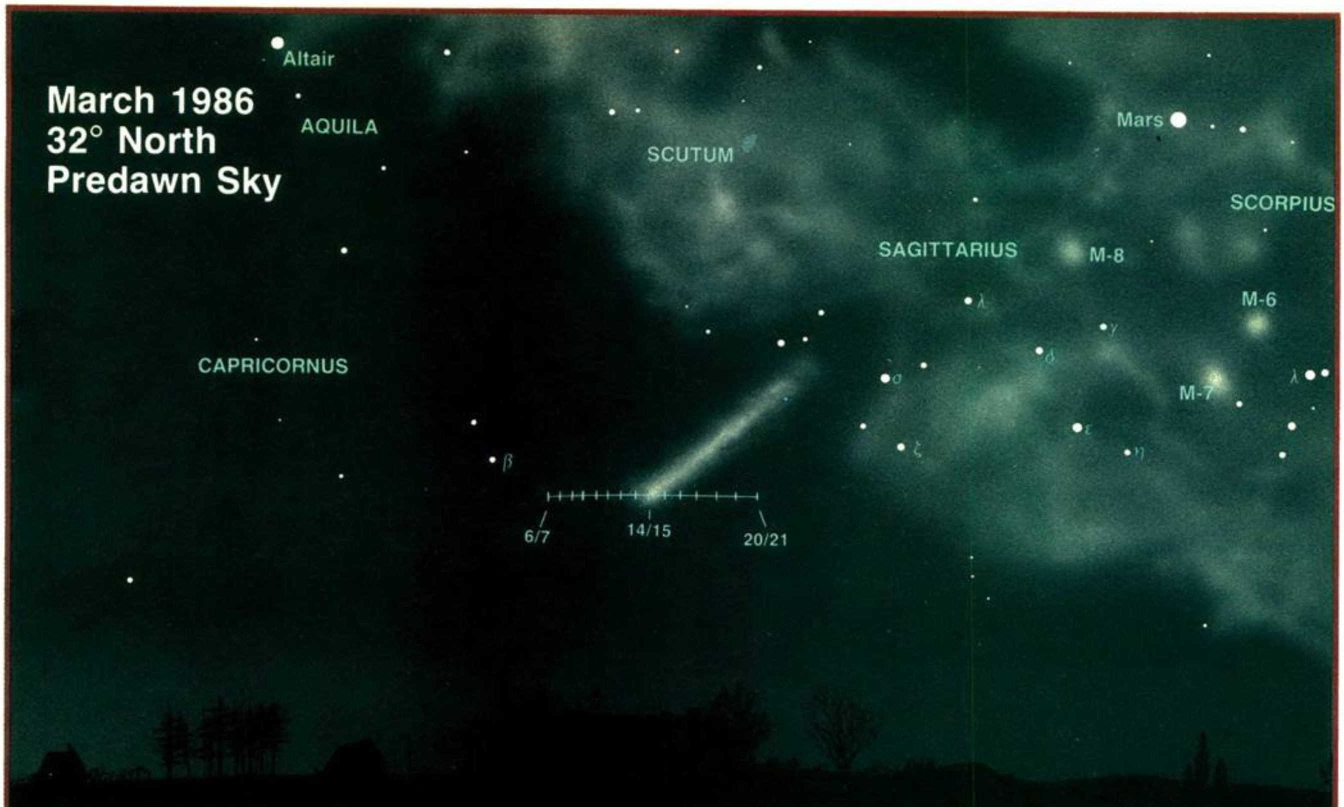
Getting the Best View

Before delving into the details of where to look for Halley, consider some important general tips on how to get the best possible view of the comet. First, get as far away from lights as possible. If you're a city-bound skywatcher, this may mean traveling at least 15 or 20 miles — perhaps even 30 or 40 — from the city. Manmade lighting easily overwhelms the comet's subtle light. Try to choose an observing site that is free from lights and has an unobstructed southern horizon since that is the part of the sky that Halley will travel across. The horizon should be flat, clear of trees, and as free as possible from haze, airports, busy roads, searchlights, or other distractions.

Another major factor is the Moon. Just as artificial lights obliterate faint objects, the Moon regularly fills the sky with reflected sunlight that drowns out relatively faint things like comets. Halley will likely be visible when the Moon is in the sky, but it will be greatly diminished. Plan on observing the comet during three Moon-free "windows" — one in March and two in April — when Halley will be up and the sky dark.

What sort of equipment will give the best views of Halley's Comet? That depends on which part of the comet you want to see. There are essentially three ways to view a comet: as a whole, as a pair of subtle tails, or as a close-up view of the tiny nucleus and surrounding coma.

If you want to get a good view of the subtle dust and gas tails, a pair of binoculars — 7x50s or 10x50s — will serve well. So-called giant binoculars — 11x70s, 16x80s, or 20x80s — will provide stunning views when used to scan the *comet from top to bottom. To observe the* nucleus, which may show finely detailed activity such as tiny jets of material streaming off, use a telescope at medium

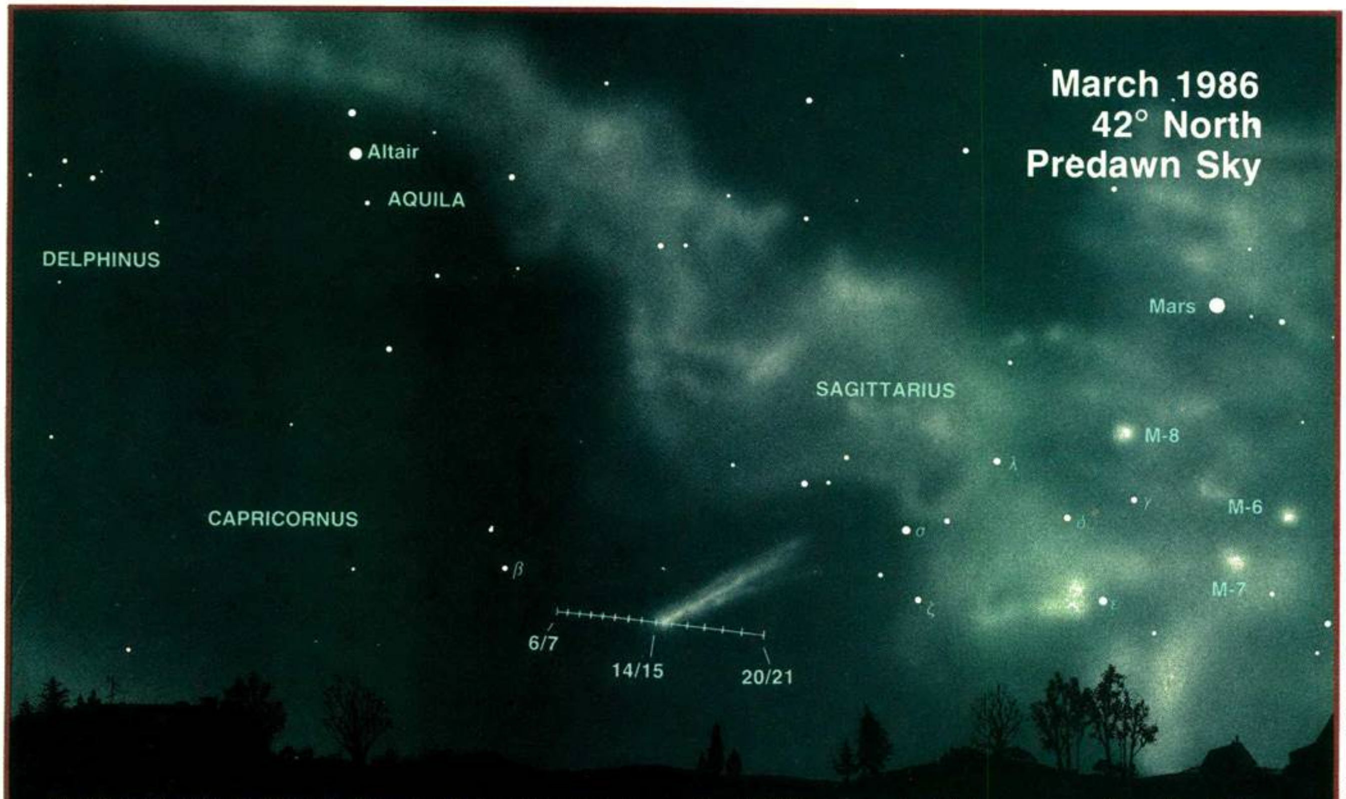


March 1986
32° North
Predawn Sky

Altair
AQUILA
SCUTUM
Mars
SCORPIUS
SAGITTARIUS
M-8
M-6
λ
γ
δ
σ
M-7
λ
ε
ζ
η
CAPRICORNUS
β
6/7
14/15
20/21

From 32° north latitude, Halley's Comet will be in the constellations Capricornus and Sagittarius during March. It will appear low in the southeastern sky shortly before sunrise. The Moon interferes until about March 7 and again during the last several days of the month. During the second week of March, Halley rises about 4:00 a.m. local time, one hour before morning twilight begins. By the time that the Moon re-enters the sky late in the month, the span of visibility will have increased by thirty minutes.

SOUTHEAST

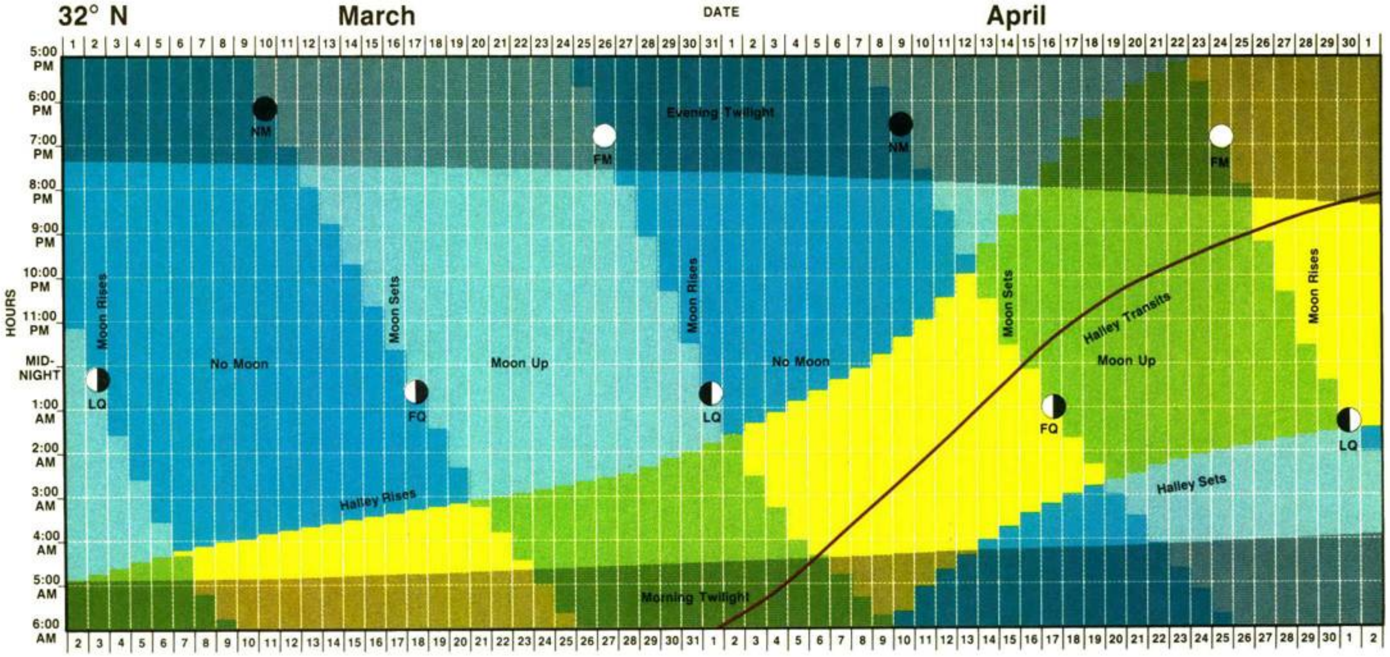


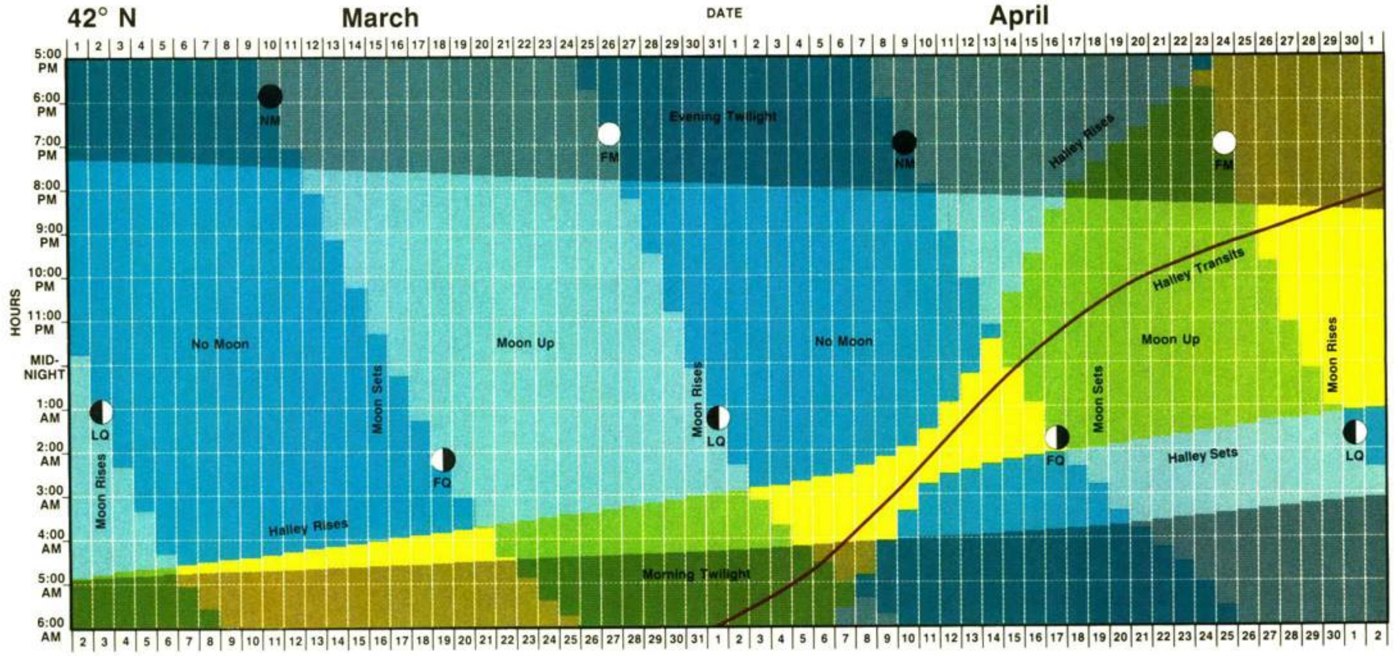
March 1986
42° North
Predawn Sky

Altair
AQUILA
DELPHINUS
Mars
SAGITTARIUS
M-8
λ
γ
M-6
σ
δ
CAPRICORNUS
β
M-7
ζ
ε
6/7
14/15
20/21

At 42° north latitude Halley's Comet will rise later than it does at 32° north. The comet will be low in the southern sky among the stars of Capricornus and Sagittarius. The Moon interferes until about March 7 and again during the last several days of the month. During the second week of March, Halley rises about 4:45 a.m. local time, about fifteen minutes before the beginning of morning twilight. When the "Moon-free" observing window ends in the third week of April, Halley rises about 3:45 a.m. and is visible for slightly over an hour before the onset of morning twilight.

Maps by David J. Eicher and Richard Berry





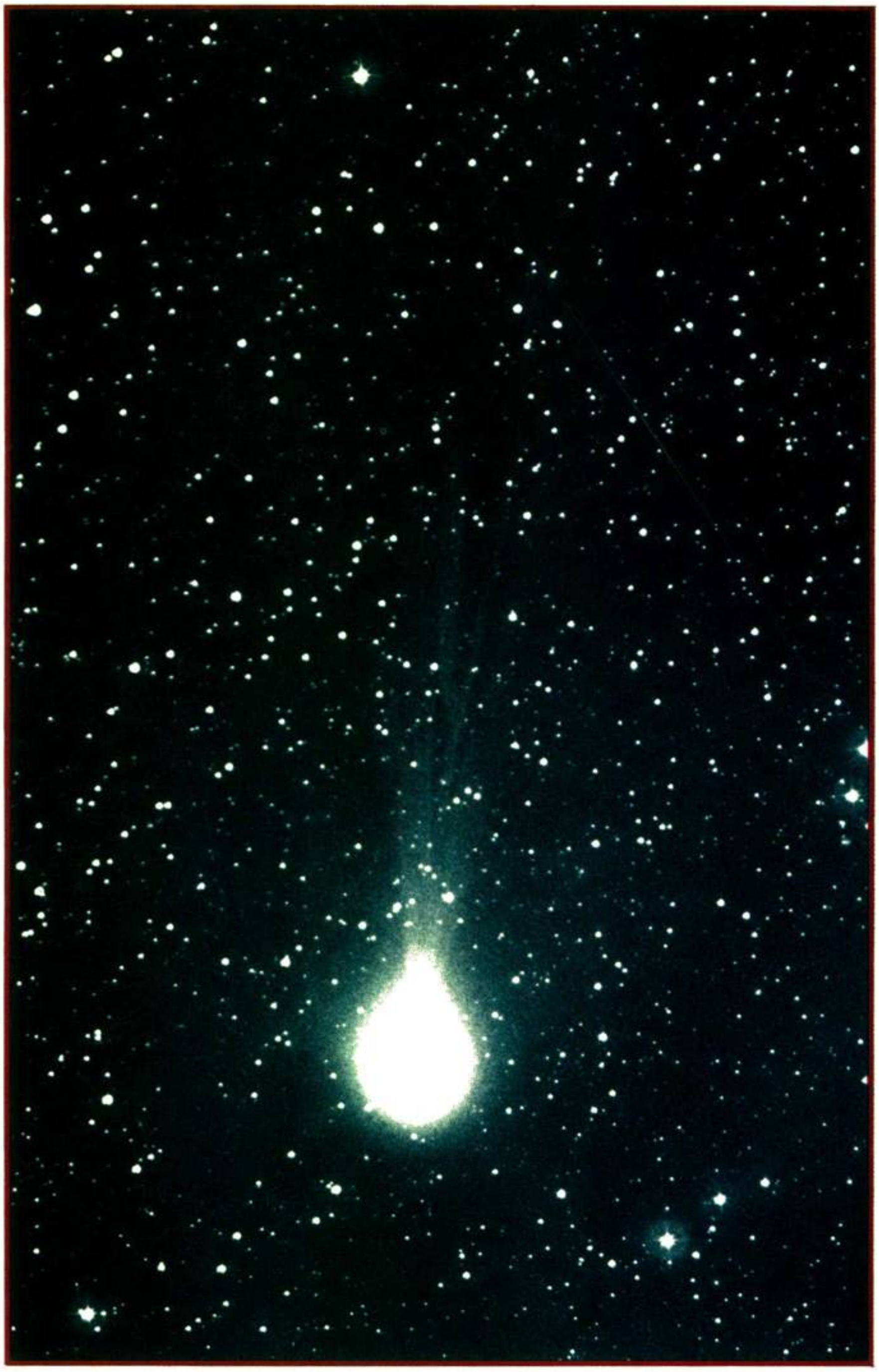
These graphic timetables for 32° north latitude (top) and 42° north latitude (bottom) provide information critical to observing Halley's Comet for each night in March and April. Plotted are the times of morning and evening twilight; moonrise and moonset; and Halley rise, set, and transit. To use the timetables, find the date along the horizontal axis and the hour of local time along the vertical axis. For example, to find when Halley is visible on March 14/15 from 42° north latitude, look on the timetable marked "42° N" and find the date along the top. On that date, the Moon is absent in the morning and Halley rises nearly 30 minutes before twilight begins. Bright yellow bars indicate the best viewing period. Graphics by D. Eicher/R. Berry/S. Myers.

to high power. The ideal instrument has 6 inches or more aperture, has been acclimatized to the outside temperature, is protected from dew by a cap, and is thoroughly familiar to the user. You may also enhance the view of some features by using various filters (see "Observing Halley's Comet With Color Filters," page 63).

During much of March and April, Halley will be visible for relatively short periods on those nights when the Moon isn't interfering. If you must travel to a dark site, arrive before the comet is above the horizon so that you'll avoid rushing to set up. Before leaving, make sure your equipment is in good shape and pack all the necessary eyepieces, tools (just in case something on the telescope goes haywire), and a red-filtered flashlight for checking maps of the comet's position. Once at your site, allow yourself twenty to thirty minutes in the dark before making serious observations; your eyes will then be completely dark-adapted.

Finding Halley from equatorial and southern latitudes will be very easy, providing skies are clear and the Moon is out of the way. Observing the comet is more difficult for observers at mid-northern latitudes, where the comet will appear lower in the sky and for a much shorter time. Halley will be completely invisible — below the horizon — from latitudes above about 50° north (see diagram on page 39).

To aid the many viewers who live in mid-northern latitudes, we have provided



During April, Halley's Comet may shine at 2nd magnitude and sport a tail some 25° long — or better. This photo, taken in December 1985, shows the comet's developing tail and bright coma. Photo by Adrian New and Robert Reeves.

maps and timetables showing where and when to observe Halley during March and April from two different latitudes — 32° north and 42° north. These graphics approximate the view from such mid-northern cities as Atlanta, Boston, Cairo, Casablanca, Chicago, Florence, Los Angeles, New York, Tel Aviv, Tokyo, Toronto, Tucson, and Vladivostok, to name just a few.

March: A Peek Before Dawn

The prospects for viewing Halley from 32° north latitude during March are quite good. At the beginning of the month, Halley rises at 4:00 a.m. local time or about one hour before the beginning of morning twilight. The Moon is a problem during the first few days of the month but is out of the way by the night of March 6/7 (the evening of the 6th and morning of the 7th), setting just after Halley rises.

If the sky is clear that morning, you'll have about forty-five minutes of dark-sky time to watch Halley. The Moon has set and the early morning sky will be filled with nothing but stars; the Milky Way shimmers along the southern horizon like a band of silver. Ruddy Mars will hang high over the Sagittarius star cloud, and the bright clusters M-6 and M-7 along with the Lagoon Nebula will appear as fuzzy spots to the naked eye.

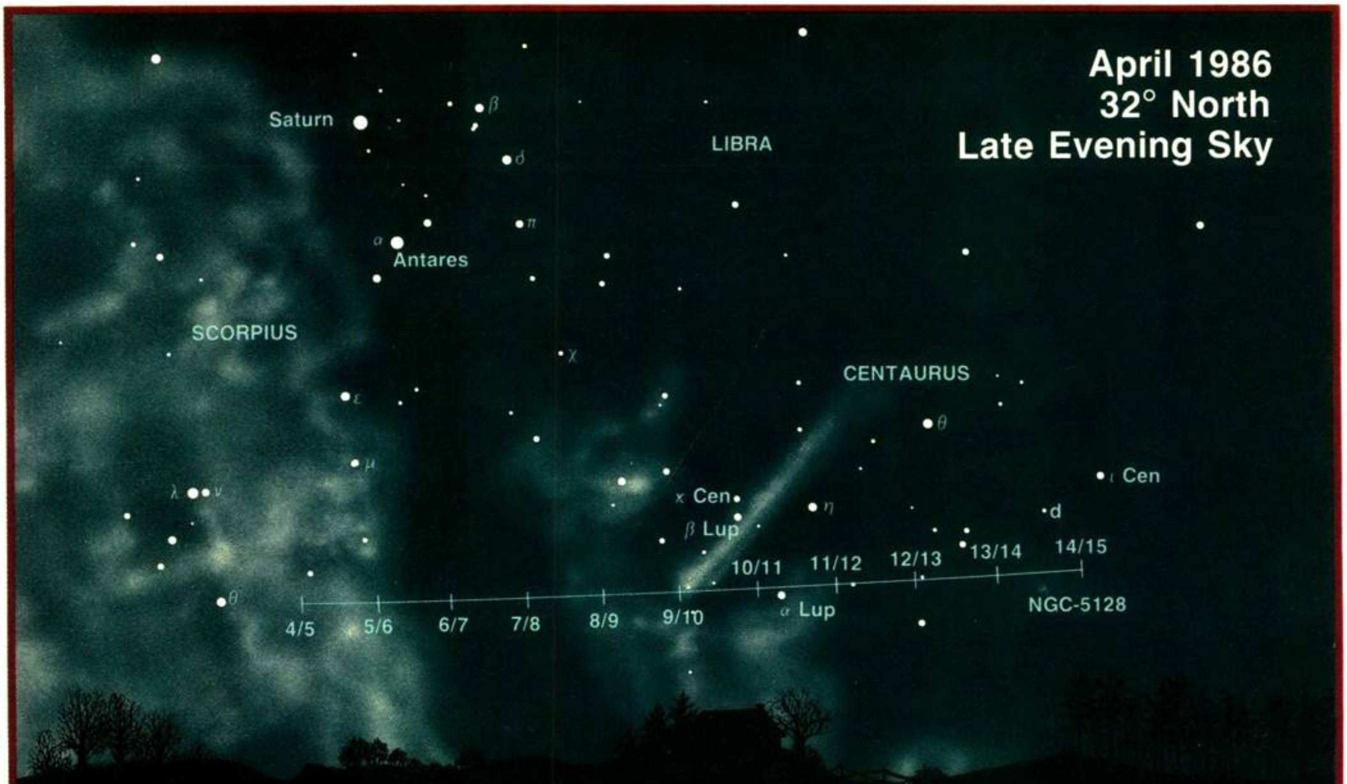
You should see a wispy brush of light rising in the southeast that appears like a detached section of the Milky Way or an airplane contrail, even though there's not a single 727 in sight. That's it — Halley's tail! The comet will grow brighter and its head should rise several degrees high. Halley's nucleus will lie about 3° south of the bright star Beta (β) Capricorni, which forms a wide pair with equally bright Alpha (α) Cap; these are the only two bright naked-eye stars in this part of the sky. Halley's gas tail will extend at a sharp angle toward the top of Sagittarius' Teapot. The comet should shine around 2nd magnitude.

This scenario will continue for several days, changing only slightly as the comet moves slowly westward and rises earlier each night. The onset of twilight also comes slightly earlier each day, but Halley stays well ahead of it. The Moon is absent from the early morning sky until March 20/21, affording a full fifteen days of dark-sky viewing. The comet should be bright enough so that you'll have no trouble finding it.

To plan observing times, check the timetable for 32° north latitude on page 36. This graph shows the beginning and ending of twilight, moonrise, and moonset, and the times of Halley rise, transit, and set. Together these show you the times when Halley is up and the sky is dark; yellow bars indicate the best times to observe the comet. The transit time shows the comet's highest elevation for any given night, which is the moment when Halley should be at its best.

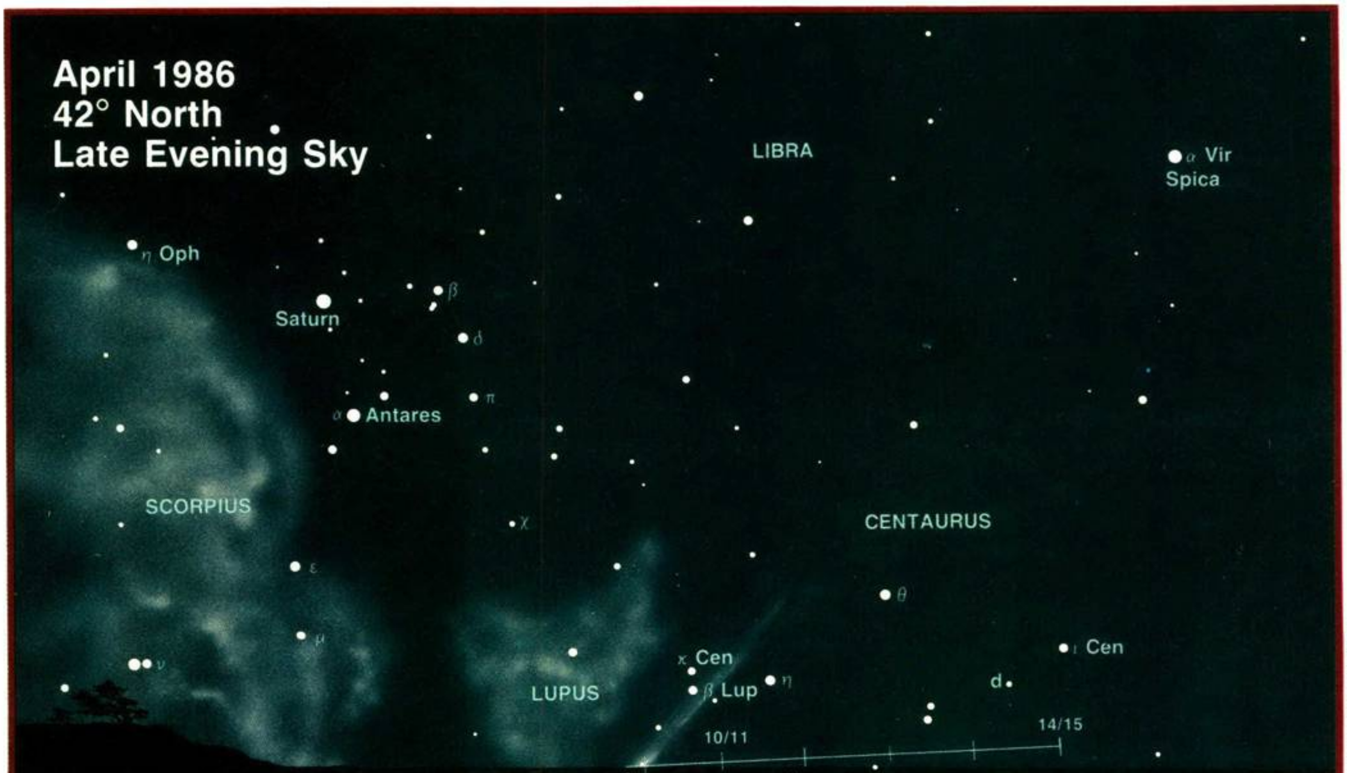
At a distance of 67 million miles from the Sun and 120 million miles from Earth, Halley is rapidly moving away from the Sun during the opening days of March. But while Halley is moving away from the Sun, it is also moving closer to Earth, which increases its apparent size, brightness, and speed across the sky as April nears. By March 10/11, the comet is 99 million miles from Earth and 78 million miles from the Sun. On March 14/15, it is equidistant from the Sun and Earth at 87 million miles, and by the evening of March 19/20 it lies 75 million miles from Earth and 93 million miles — one astronomical unit — from the Sun.

The view is not nearly as good for observers at 42° north latitude. During March, the comet rises later and does not get as high in the sky before the dawn overtakes it. The first opportunity for moonless viewing comes early in the morning on March 6/7 when the Moon rises at 5:00 a.m. local time, some fifteen minutes after morning twilight begins. Halley rises at 4:30 a.m. local time, affording only a very few minutes for gazing at the comet under a dark sky. The situation improves during the following days, and by March 14/15 — the date on which Halley is shown on the 42° north map — the comet rises nearly thirty


April 1986
32° North
Late Evening Sky
Saturn
β
δ
LIBRA
α
Antares
π
SCORPIUS
χ
CENTAURUS
ε
θ
μ
ι Cen
λ
ν
κ Cen
η
d
β Lup
10/11
11/12
12/13
13/14
14/15
θ
4/5
5/6
6/7
7/8
8/9
9/10
α Lup
NGC-5128

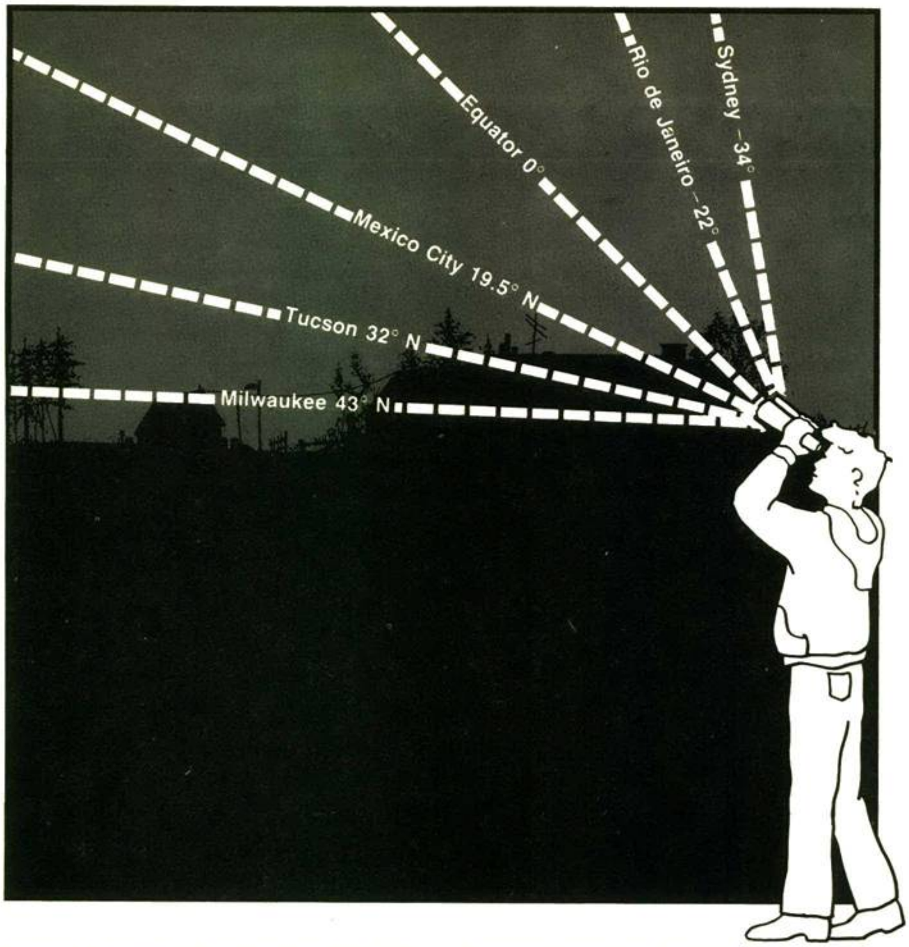
From 32° north latitude, Halley's Comet will be at its highest elevation during the early morning hours as it moves through the stars of Scorpius and Centaurus during April. During the first week of April, Halley rises at about 1:00 a.m. local time and is at its highest in the southern sky shortly before sunrise. However, the comet swiftly becomes a late evening object, and by April 11/12 it rises at about 10:30 p.m. local time and gains highest elevation by about 2:00 a.m. local time.

SOUTH


April 1986
42° North
Late Evening Sky
η Oph
Saturn
β
δ
α
Antares
π
LIBRA
α Vir
Spica
SCORPIUS
χ
CENTAURUS
ε
θ
μ
ν
LUPUS
κ Cen
β Lup
η
ι Cen
d
10/11
14/15

From 42° north latitude, Halley will be rather difficult to view during most of April. It rises much later than it does as seen from 32° north latitude. Although its position among the stars of Scorpius and Centaurus is the same, the comet will appear lower in the sky. In the first week of April, Halley rises shortly before 3:00 a.m. local time and gains highest elevation just before dawn. By the second week of April, the comet rises about 1:00 a.m. local time and just skims the southern horizon during the early morning hours. During the final days of the month, *as an evening object in the southwestern sky*, Halley lies 15° above the horizon at about 9:00 p.m. local time.

Maps by David J. Eicher and Richard Berry



This spring, latitude plays a critical role in observing Halley. The famous comet is invisible from higher than 50° north, is low in the sky from 40° north, and is high in the sky only south of the equator. Diagram by Susan Myers.

minutes before twilight begins. The 32° north latitude map shows much the same scene as the 42° version, although the constellations, Halley, Mars — everything — appears higher on the southern horizon. By March 19/20 Halley rises about 3:45 a.m. local time, giving observers forty-five minutes to be with Halley under a dark sky.

April: On Into the Evening

In April, Halley really shows its stuff because the combined movement of the comet and Earth brings Halley to its closest approach to us. On April Fool's Day, Halley is some 110 million miles from the Sun but a mere 49 million miles from Earth. The night of April 9/10 is Halley's closest approach — 39 million miles — when the comet reaches its brightest.

Because it's relatively close to us, Halley's apparent motion during April increases greatly. This, coupled with Earth's motion, causes the comet to move from the morning to the evening sky as the month progresses.

The scene from 32° north latitude in April is quite different from that of one month earlier. The first opportunity to observe Halley under a completely dark sky comes on the night of April 2/3, when Halley rises shortly after 1:00 a.m. local time and the Moon is out of the sky until nearly 2:30 a.m. During early to mid-April, you'll have a chance for lengthy observing periods under a dark sky. On the night of April 2/3, Halley's nucleus will lie a few degrees east of the tail of Scorpius, smack in the middle of the rich southern Milky Way. Bright orange Saturn will hover 5° above equally orangish Antares, the Scorpion's brightest star.

The following nights become even better, with Halley rising earlier and the Moon rising later. On April 4/5, the comet lies between and slightly below the bright stars Theta (*θ*) and Eta (*η*) Scorpii and rises at 12:50 a.m. local time. The Moon isn't up until 4:00 a.m., by which time the comet's nucleus is a comfortable 10° high.

The location of the comet on April 9/10, the night of closest approach, is shown on the 32° north latitude map on page 38. (The comet's position on the five nights preceding and following that date are also plotted as tick marks.) That night should be memorable: Halley will be at its brightest, 2nd magnitude or perhaps brighter, and sporting a tail as much as two dozen degrees long sticking up out of the rich Milky Way in Lupus. Halley will rise at about 11:20 p.m. local time and be some 10° above the horizon by 2:00 a.m. The New Moon won't present any problems.

A curious event will occur on April 14/15 when Halley's nucleus passes virtually right across the bright elliptical galaxy NGC-5128, also known as radio source Centaurus A. From 32° north latitude, the two objects will be nearly 16° high in the southern sky at 11:50 p.m., shortly after moonrise. Try observing the comet with a pair of binoculars; if you see a 7th-magnitude fuzzball some 12′ across near the comet, you're observing a historic meeting of comet and giant lenticular galaxy.

The Moon interferes with viewing Halley during the third and fourth week of April, but by the 26th the comet will again be visible in the evening sky as soon as evening twilight ends.

Halley will also be visible during the last days of April but will have moved some 65 million miles away from Earth (and 145 million miles from the Sun), already beginning its speedy disappearing act. The comet will still be visible, though, but by the end of April the best views will have been had and the best photographs taken.

Viewing Halley's Comet from 42° north latitude during April is far worse than observing from 32° north, as a glance at the timetable shows. From 42° north, the comet will be much lower in the sky and its apparent motion is such that it moves roughly parallel to the horizon. On the night of April 2/3 it will rise at about 2:45 a.m. local time, some twenty minutes before the Moon. On April 4/5, the comet will be up at 2:30 a.m. and the Moon won't rise until twilight begins at 4:10 a.m. local time. Even so, Halley will only be about 7° above the horizon — hence the need for a clear, unobstructed view.

The night of closest approach, April 9/10, is actually *not* the best time to view Halley from 42° north latitude. At its highest elevation, which it reaches at 2:00 a.m., Halley's nucleus will skim less than ½° above the horizon. The comet's long tail may extend upward through the constellation Centaurus and its bright star Kappa (**κ**) and also through Lupus' dazzling Beta (*β*). At this point, you are at the mercy of horizon haze. Better viewing opportunities will come during the following days until about April 12/13. By then, Halley will rise at about 12:10 a.m. local time and reach an elevation of some 5° by 1:30 a.m. The comet's elevation will be even higher on April 19/20 — some 15° by 9:10 p.m. local time — but by then the Moon will return to wreak havoc on the poor comet's frail light.

Now that you have all this precise (if somewhat less than optimistic) information about observing Halley's Comet, there's one overriding consideration to keep in mind: go out *now*, whenever skies are clear, because Halley will be gone before you know it. Years from now after the memory of all the hoopla, press coverage, T-shirts, and coffee mugs has faded, you will be able to look back and remember standing out under the stars during a chilly spring morning and seeing that long misty tail pointed skyward.

— *David J. Eicher*

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$369
295

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• $90 #124 2x or 3x Barlow	$\$67^{50}$
• $80 #127 2x-3x variable Barlow	$\$59^{50}$
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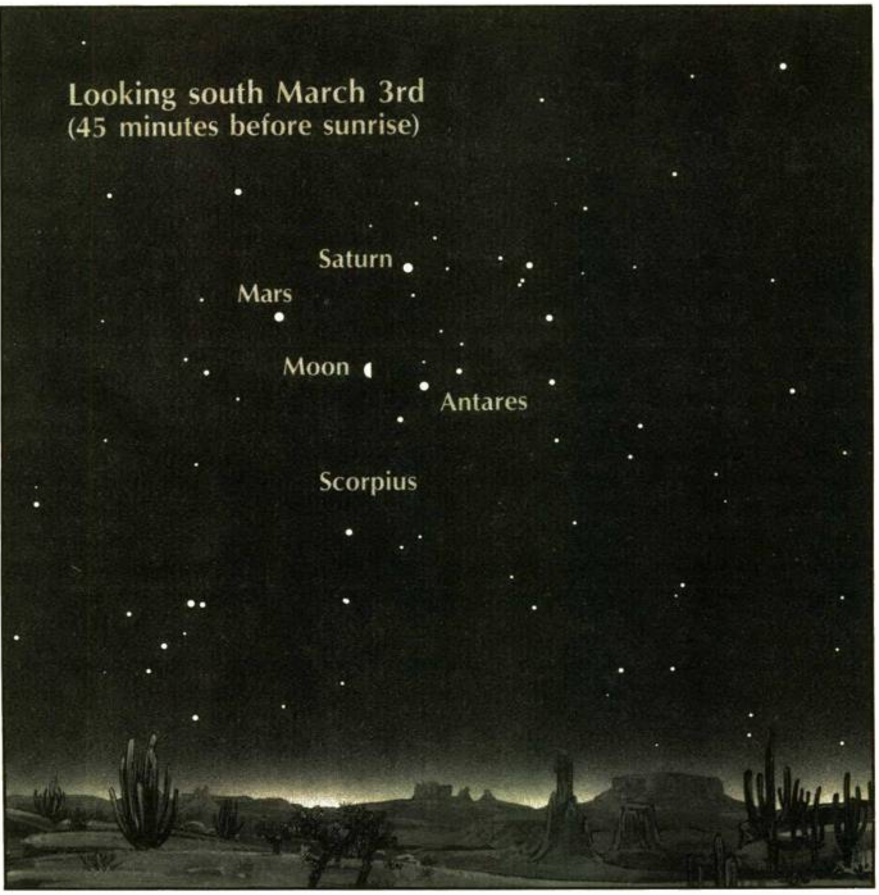
Eye on the Sky

Jupiter Gleams in the Morning Sky

by
Fred Schaaf



Right: Aurora often lightens the nighttime sky over Alaska. Forrest Baldwin of Wasilla, Alaska, took this photo of an auroral curtain with a 50mm f/1.4 lens and a 4-second exposure on Ektachrome 400 film.

The Wanderers

This month and next, **Halley's Comet** will be at its best and brightest. For full details on how to see it in March and April, turn to the Gazer's Gazette on page 46.

Mercury and Venus, the two planets that circle the Sun inside Earth's orbit, are both briefly visible this month. During the first few days of March, **Mercury** can be seen low in the southwest during the hour after sunset. It is a tawny dot about 1st magnitude in brightness but will look dimmer in the twilight sky. Mercury won't remain visible for long: on the 16th it passes between the Earth and Sun (inferior conjunction) and moves into the morning sky. **Venus** was at superior conjunction in mid-January and is moving slowly into the evening sky. Try looking for the planet very low in the southwest after sunset during the second half of March. It will be a bright white "star" of about −4 magnitude.

The other planets visible to the naked eye are in the morning sky. Get up about an hour and a half before sunrise and go to a location that has a clear view of the eastern and southeastern horizon.

At 4:30 a.m. on March 15th, the sky will show the stars of summer rising in the east (see the star map on page 44 of the June 1985 issue). **Saturn** is a creamy white object about as bright as the star Spica in Virgo. The planet lies in southern Ophiuchus, north and a little east of the ruddy star Antares in Scorpius. Essentially motionless against the star background in March, Saturn will gradually move toward the west over the next few months. Use Antares as a *"zero point"* to gauge Saturn's drift.

Mars lies to the east of Saturn and is the nearest bright planet to it this month. The planet's ruddy color is similar to that of Antares, although it shines about one magnitude brighter. Mars' motion is toward the constellation Sagittarius to the east. On the morning of March 13th, Mars will pass just 21 arc-minutes (two-thirds the diameter of the Moon) north of Uranus. But you will need binoculars or a small telescope to discern the 6th-magnitude dot of light that is Uranus.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Our last naked-eye planet is **Jupiter**. It has been in conjunction with the Sun but returns to view in the predawn sky this month. It will be low in the east as dawn begins to lighten the sky. Look for a white object at −2 magnitude between the star Altair in Aquila and the horizon.

The Starry Sky

When you step out to look at the night sky in March, the first thing you'll notice is that it lacks the bright stellar jewels that mark the winter and summer heavens. The constellations of spring are dimmer and less flashy. Let's ignore the departing stars of winter in the western half of the sky and focus our attention high in the south where the spring constellations array themselves.

In a constellation so dim that no star in it shines brighter than 3rd magnitude, there lies one of the sky's finest star clusters. The constellation is **Cancer** the Crab and the cluster is number 44 on the famous list compiled by French comet hunter Charles Messier.

M-44 carries several nicknames, among them the Beehive, Praesepe, and the Manger. "Beehive" certainly describes the cluster's appearance through binoculars or other low-magnification optics. Such views are the most pleasing ones of M-44, but the naked-eye sight is quite eerie and beautiful in its own right, at least in a dark sky.

Even for spring constellations, this group is dim. Under a sky hazily luminous with light pollution, spotting Cancer's stars is extremely difficult. The best approach is to look halfway between the bright star Regulus in **Leo** the Lion and the "Twin" stars Pollux and Castor in **Gemini**.

From a dark-sky location, however, Cancer's stars are easy to pick out and M-44 should appear as a softly glowing puff of light in the center of the constellation. (Be sure to bring binoculars along to confirm the sight.)

Gemini's two bright stars form the rear guard of the winter constellations. Just fainter than Pollux (1st magnitude) and Castor (2nd magnitude) is Gamma (γ) Geminorum, a star in the Twins' southern feet that is often called Alhena or

March's Night Sky

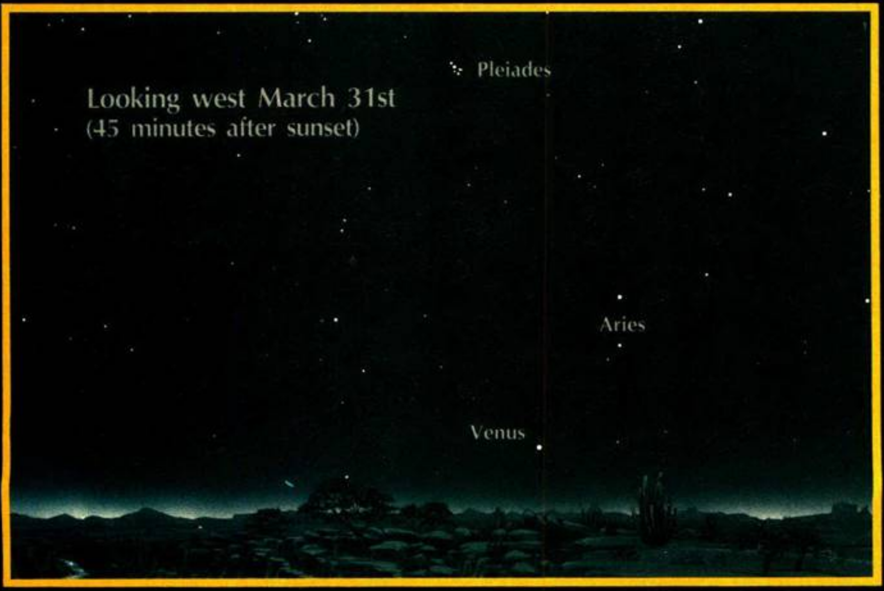
Last Quarter
March 3
7:17 a.m. EST

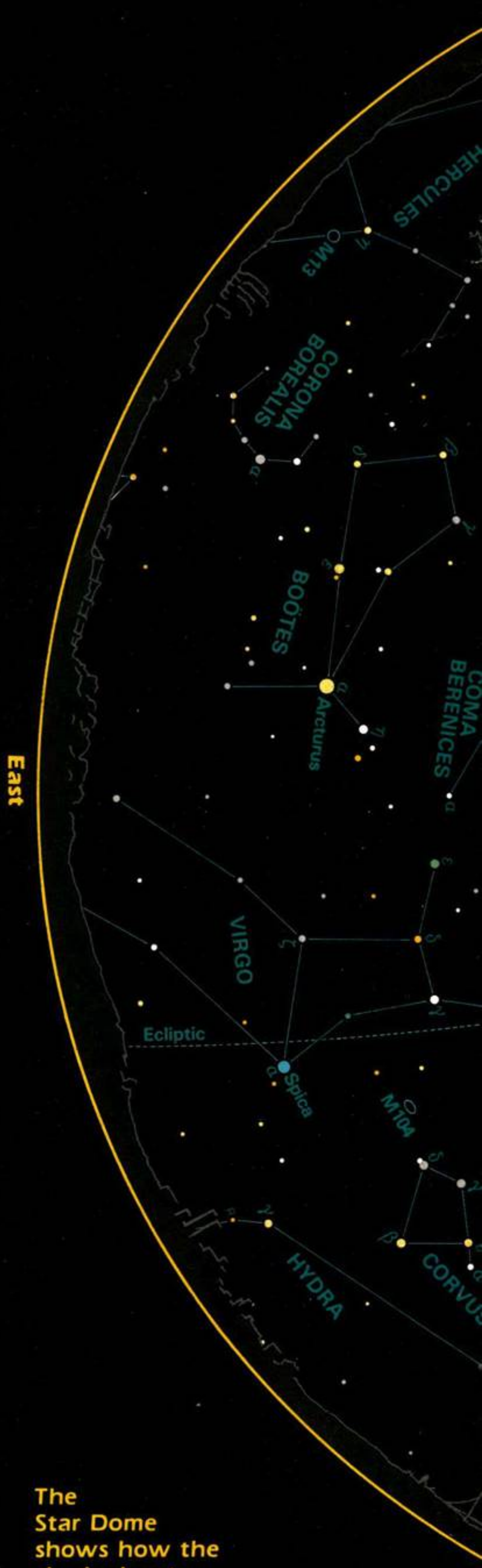
New Moon
March 10
9:52 a.m. EST

First Quarter
March 18
11:39 a.m. EST

Full Moon
March 25
10:02 p.m. EST

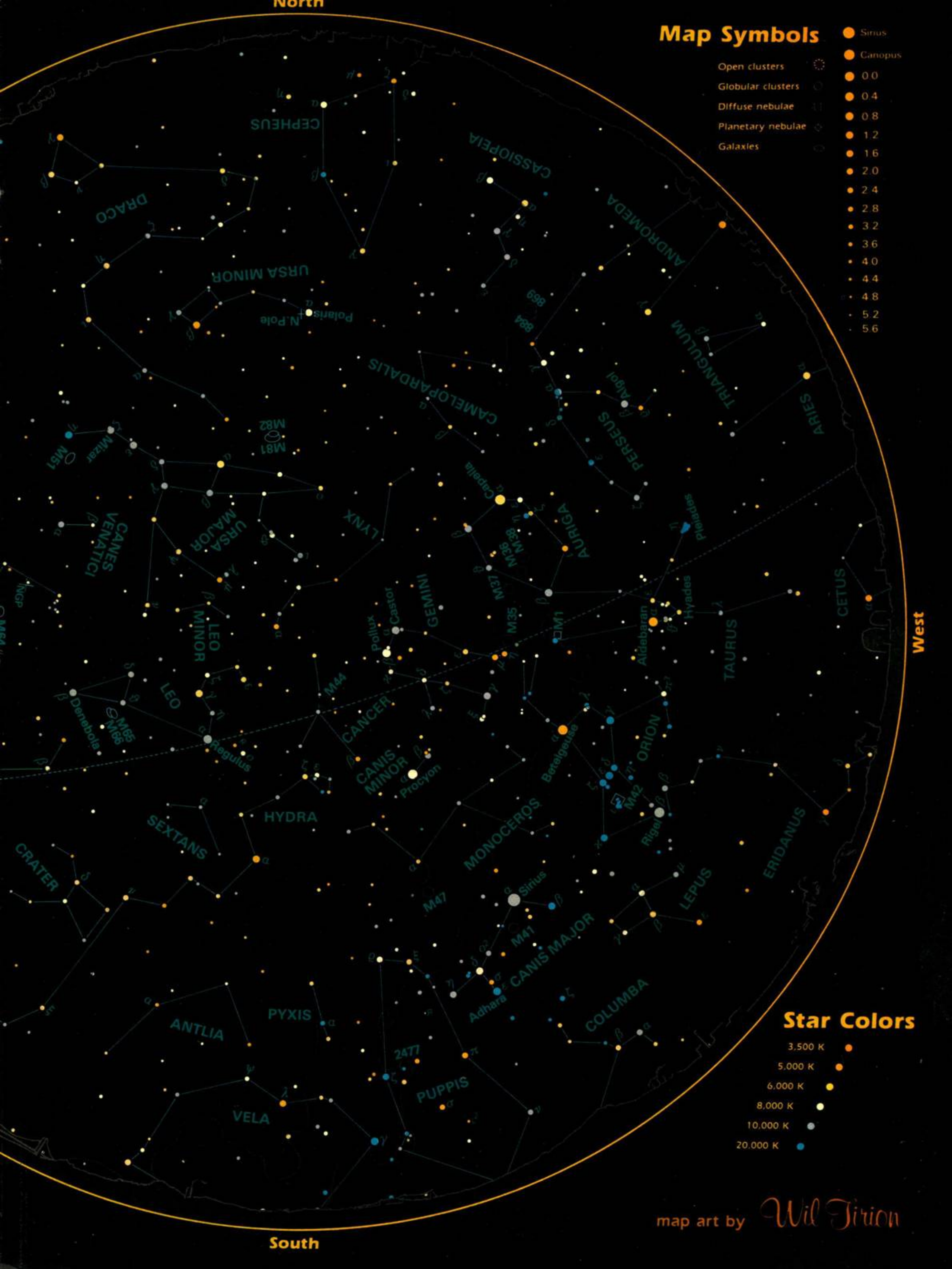
1st	The Moon is close to Earth at 4:32 a.m. EST: 229,394 miles. Mercury will be visible low in the southwestern sky immediately after sunset for the next few days.
3rd	Last Quarter Moon occurs at 7:17 a.m. EST. The Moon passes south of Saturn and north of Mars.
10th	New Moon is at 9:52 a.m. EST. Comet Halley crosses the celestial equator, moving south in declination.
12th	At 2 a.m., as Spica in Virgo crosses the meridian, the Milky Way lies around the entire horizon.
13th	Mars passes less than half a degree south of Uranus in the morning sky.
15th	The 1st-magnitude star Regulus lies due south at 10:30 p.m.
16th	The Moon is farthest from Earth at 2:50 p.m. EST: 251,419 miles. Mercury is at inferior conjunction, passing from the evening sky into the morning sky.
18th	First Quarter Moon occurs at 11:39 a.m. EST.
20th	Spring begins at 5:03 p.m. EST, when the Sun crosses the celestial equator moving northward in declination.
21st	Start looking for Venus very low in the southwest after sunset.
25th	The Moon is Full at 10:02 p.m. EST.
28th	The Moon is again close to Earth (for the second time this month) at 8:53 a.m. EST: 226,153 miles.


Pleiades
Looking west March 31st
(45 minutes after sunset)
Aries
Venus

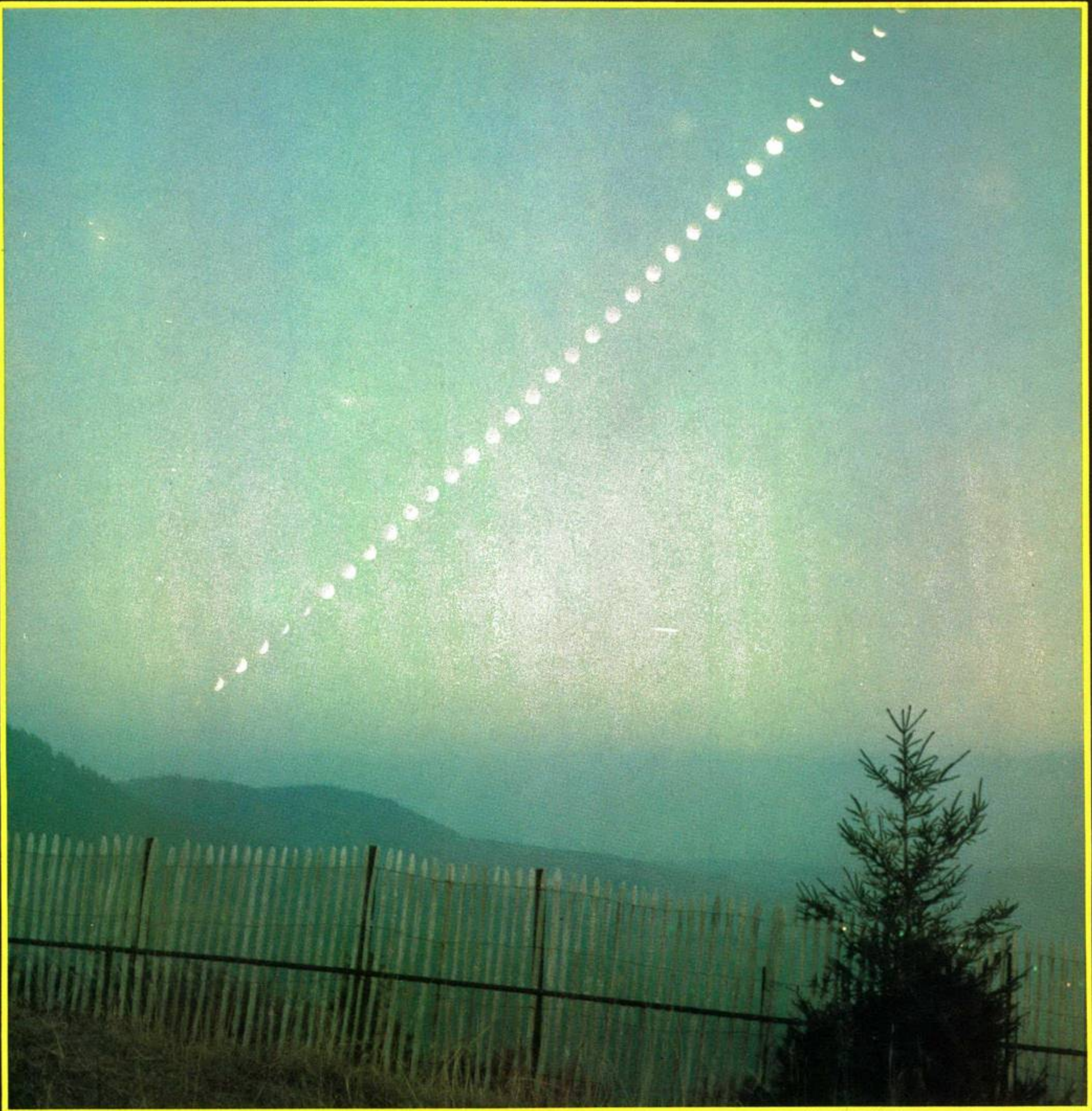

HERCULES
M13
CORONA BOREALIS
BOÖTES
Arcturus
COMA BERENICES
East
VIRGO
Ecliptic
Spica
M104
HYDRA
CORVUS

The
Star Dome
shows how the
sky looks at:

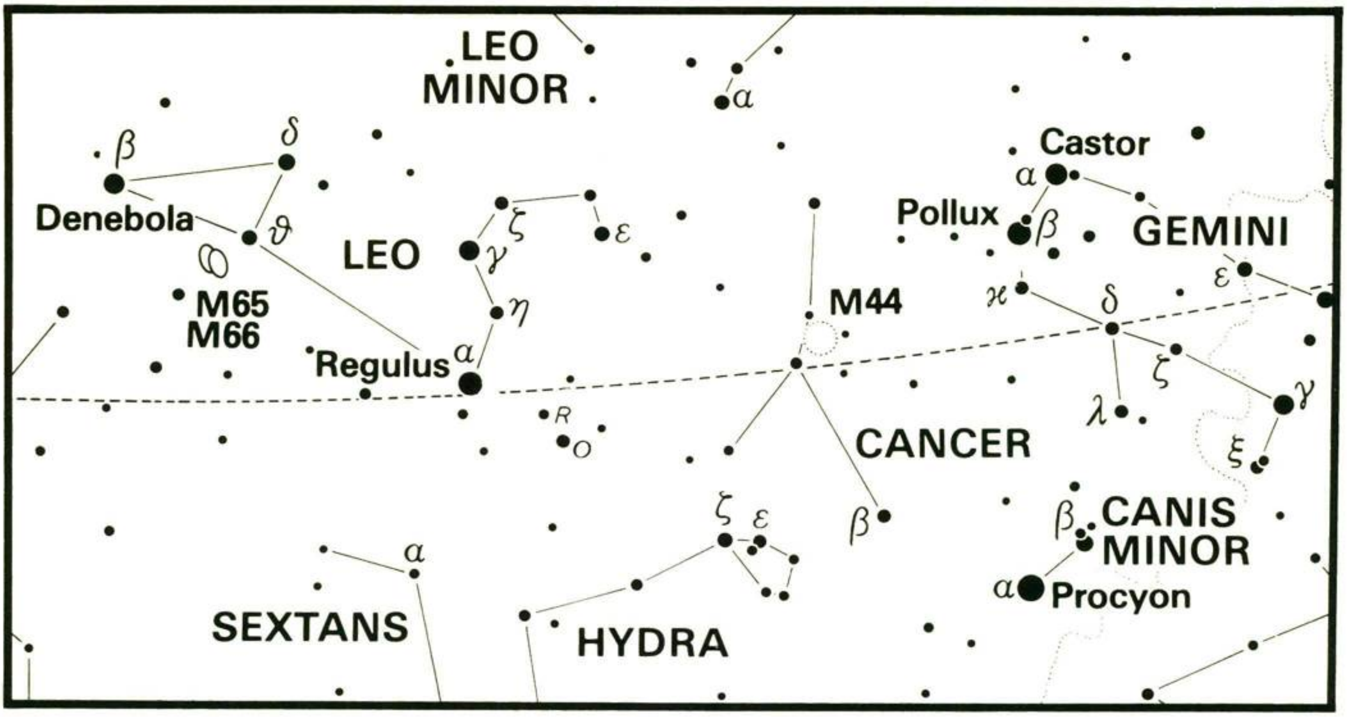
10:30 p.m. on March 1st
9:30 p.m. on March 15th
8:30 p.m. on March 31st


North
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
CEPHEUS
CASSIOPEIA
DRACO
ANDROMEDA
URSA MINOR
Polaris
N. Pole
869
884
TRIANGULUM
CAMELOPARDALIS
Algol
PERSEUS
ARIES
M82
M81
M51
Mizar
Capella
Pleiades
CANES VENATICI
URSA MAJOR
LYNX
AURIGA
M36
M38
M37
CETUS
NGP
LEO MINOR
GEMINI
Castor
Pollux
M35
M1
Hyades
Aldebaran
TAURUS
West
Denebola
M85
M66
LEO
M44
CANCER
Regulus
Betelgeuse
ORION
CANIS MINOR
Procyon
M42
Rigel
HYDRA
SEXTANS
MONOCEROS
ERIDANUS
CRATER
M47
Sirius
LEPUS
M41
CANIS MAJOR
Adhara
PYXIS
ANTLIA
COLUMBA
2477
PUPPIS
VELA
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
South

map art by Wil Tirion



On October 28, 1985, a total eclipse of the Moon was visible over Europe, Asia, and parts of the western Pacific. Above: Juergen Knobloch was in the French Alps near Geneva when he took this multiple-exposure sequence of the Moon as it was simultaneously rising and being eclipsed. He used 127-format Kodacolor film (ISO 100) and a 65mm lens. Exposure times ranged from $\frac{1}{125}$ second at f/8 outside totality to 8 seconds at f/4 during totality. Knobloch let 4 minutes elapse between each exposure; residual skylight lit the landscape. Left: Elaine Clark photographed the same eclipsed Moon from northeastern Australia just before totality began. She used a 500mm f/8 lens, VR 1000 film, and a 2-second exposure.



Almeisan. Another curious star in the Twins is Delta (δ), which is also known as Wasat (pronounced WAY-sat). Clyde Tombaugh discovered Pluto near this star in 1930. The discovery was announced 56 years ago this month (see Forum, February 1986).

Pluto was not the only planet to be discovered in Gemini: 205 years ago this month (March 13, 1781), William Herschel found Uranus near Eta (η) Geminorum using his homemade 6-inch reflector. Eta is a semi-regular variable star, but its 0.8-magnitude range of variation is hard to detect without experience.

Let's return a moment to Cancer and look a short distance to the south. Halfway between Regulus and Procyon in Canis Minor lies a fairly faint pattern of stars. This is the head of **Hydra** the Sea Serpent. Hydra is a long constellation that snakes southeastward toward the constellations of summer. Just to the south of Hydra's head is where Halley's Comet hibernates during the long decades when it is near aphelion.

Skylore

This spring, Halley's Comet passes through two constellations that represent the imaginary beings, half-man and half-horse, called centaurs. The first is Sagittarius the Archer, which the comet cuts through this month; the second is Centaurus the Centaur, which the comet will enter next month just after closest approach to Earth.

A centaur is a man down to the waist and a horse from there on. The origin of the mythical centaur is a matter of conjecture, but some speculate that the legend stems from primitive peoples' astonishment at seeing for the first time a man riding on horseback.

The sky's most ancient centaur seems to be Sagittarius, judging by its important place in the zodiac. Centaurus was a southerly constellation for the ancient Greeks, though twenty centuries of precession have now moved it further southward.

Oddly enough, the earliest Greek writers (Hesiod and Homer) apparently regarded centaurs as entirely human in form; the creatures' inhumanity or wildness lay only in their temperament, customs, and origin. From at least the time of the poet Aratos (a few centuries B.C.), however, the constellation Centaurus was called "the Horseman Beast" and presumably bore its current demi-equine form.

Although the two celestial centaurs have long been confused, there seems to be a tradition that Sagittarius was a typical fierce centaur and that Centaurus was atypically gentle. This means that Centaurus is the more likely star group to represent Chiron (pronounced KYE-ron), the most famous, wise, and gentle of the species.

Taught by Apollo and Diana, Chiron became a master of much knowledge including botany and medicine, music and astronomy. He was reputed, in fact, to have invented the constellations — a substantial and honorable accomplishment, to be sure! According to one tradition, Chiron invented the constellation Sagittarius especially for the guidance of Jason's Argonauts on their quest for the Golden Fleece. Euripides said that Chiron's son Hippo was able to divine future events from the stars.

Chiron became a sage and teacher; his pupils were many of the great heroes and healers of Greek mythology. Jason and Achilles both studied under him, as did Aesculapius, a quasi-historical figure who became the god of medicine. Aesculapius is commonly regarded as the figure depicted in the constellation of Ophiuchus, which lies near both Sagittarius and Centaurus.

Another constellation connected with Centaurus is Hercules. A pupil of Chiron's, strongman Hercules accidentally shot his teacher with a poisoned arrow, but since Chiron was immortal, the poison didn't kill him. Nevertheless, Chiron languished in extreme agony until the repentant Hercules struck a deal with Zeus. For stealing fire from the gods and giving it to mortals, Zeus had chained the god Prometheus to a rock. Zeus told Hercules that Prometheus could be freed only if another immortal was willing to die and go to the underworld of Tartarus in his stead. Hercules knew that Chiron sought to end his own suffering by death. Finally, two misfortunes were ended: the centaur Chiron went to Tartarus and Prometheus was allowed his freedom by Hercules.

Chiron appears in numerous myths, but over the centuries various people have argued that he may have originally been a real person. According to R.H. Allen, St. Clement of Alexandria wrote that it was Chiron who first led mortals into righteousness. Allen also states that Isaac Newton believed the story of Chiron was "in some degree historic."

In our time, Chiron's name has been given to a strange object, discovered in 1977 by Charles Kowal, that orbits the Sun between Saturn and Uranus. Astronomers still do not know if Chiron is the most distant known asteroid, the largest known comet nucleus, or, like some strange "planetary centaur," a hybrid form of body.

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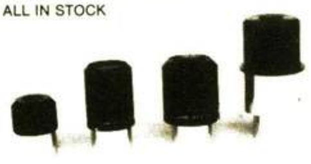

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1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$159.50**	**$199.50**
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**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

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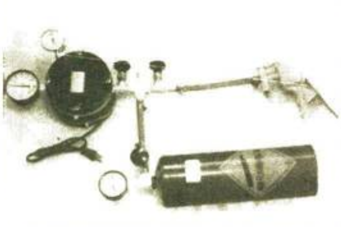

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- ★ **Optional:** Multi-coated/silvered optics boost transmission 18%, **add $149**

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The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see above.)

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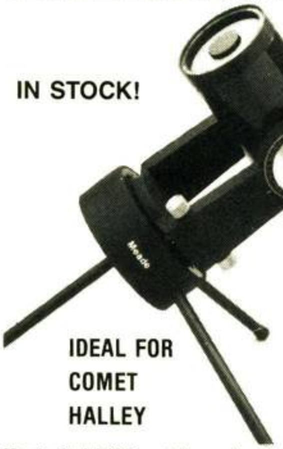

Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THIS TELESCOPE

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- ★ Sturdy fork mount with setting circles
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- ★ Star map & red astronomer's flashlight

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($120 List)	$96
See Meade 2080/LX2 options	
Wedge & field tripod as for 2080/LX2	$298
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Identical to 310, but has equatorial mount with setting circles.

Quartz motor drive	$169
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48mm Prem Deep-Sky	**$119.50, $99.95** w/ Easy-Guider
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#122 2X Barlow ($60 list)	$48
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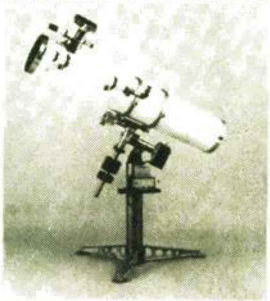

Model 826, 8" f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)	$750
Model 628C, 628 w/2" focuser, 8x50mm finder ($1350	$850
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#43 drive corrector uses 12VDC ($120 list)	$96
#47M Dual-axis drive corrector & elec. dec.	$340
1¼" or 2" EASY-GUIDER (state camera)	$149

6" f/5 NEWTONIAN........ $695

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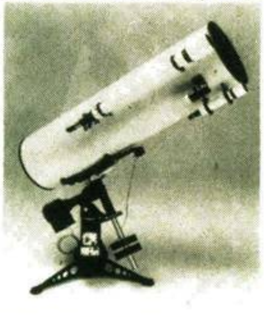
1¼" LUMICON Easy-Guider (state camera)	$149

16" f/4.5 NEWTONIAN $1995



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DS-16A, 16" f/4.5 with motor drive ($3050 list)	$1995
Sealmaster ball bearings, highly recommended	**add $229**

—Gathers 400% more light than an 8" telescope

Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces.

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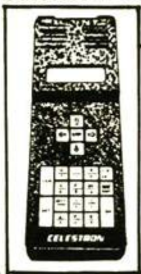

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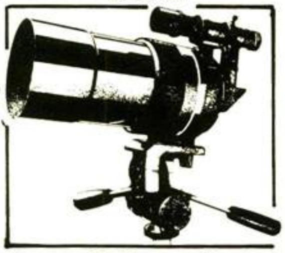

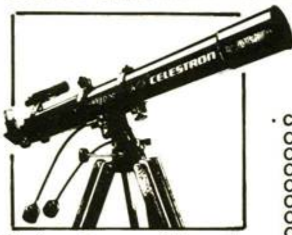

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Observing Halley's Comet With Color Filters

by
Charles F. Capen

Comet West was a bright, colorful feature in the skies a decade ago. R. Townsend's photo, taken on March 5, 1976, clearly shows the comet's straight, blue gas tail separate from the curving dust tail (which appears white in this image).

Well, it's finally here. And by now everyone who can get, beg, borrow, or steal an optical instrument is eagerly scanning the skies to see The Famous Comet.

Like you, I plan to be outside every clear night, moonlit or not, grabbing all the views I can. But I'm going to be doing something a little different from ordinary observing. I'll be viewing the comet through colored filters.

Filters? For a comet?

Yes, filters. Comets, although they look white to the casual observer, actually have a substantial amount of color, albeit subtle. Observing through color filters brings out certain features in a comet and increases their apparent contrast. Filters also improve the view during twilight and let you study the changes that occur in a comet's appearance.

Basic Equipment

Happily, filtered comet viewing can be done with any optical instrument. 7x50 binoculars are good and 11x80's are excellent; rich-field telescopes are also ideal. Look for instruments that have 5 to 7 millimeter exit pupils, for these gather light most efficiently. If you observe with binoculars, get a tripod adapter from a photo store and attach them to a sturdy tripod.

Light-gathering power and wide field are ultimately more important than magnification because, even at best, the comet will be fairly dim. Bright images and wide fields of view come with low eyepiece magnifications. With a telescope use powers from 10x to 40x, reserving 50x to 150x for detecting features within the comet's head. A good, all-around rule of thumb for magnification is 4.5x per inch of aperture.

Types of Color Filters

If you've shot much black and white film, the word "filter" probably brings to mind the old red Wratten A filter. Forget it. Filters like that are far too dense. The filters you'll need are lighter in color and have higher transmissions. A good starter set will include the yellow Wratten 4 or 8, the green Wratten 56 or 58, the blue Wratten 82A or 80A, and the magenta Wratten 30. The orange Wratten 21 and the light red Wratten 23A make useful additions for very bright or sungrazing daylight comets.

Some of these filters may already lurk in the depths of your camera gadget bag. Those you lack are available at most well-stocked photo stores. Kodak sells Wratten filters as 2-inch gelatin squares, which can be cut and mounted in standard 35mm glass slide mounts. (Glass mounts protect the soft surface of the gelatin.) Or you can get circular glass filters from telescope accessory companies that screw into the end of an eyepiece.

Filters transmit light of their own color and block complementary colors. Thus a red object will appear brighter than its surroundings when viewed through a red filter. Conversely, to *darken* an object with a reddish color, view it through a blue filter. Most comets appear a luminous bluish white color, but some have a dusty reddish hue and a few sungrazers have been known to emit light in the yellow (sodium D line) region of the spectrum.

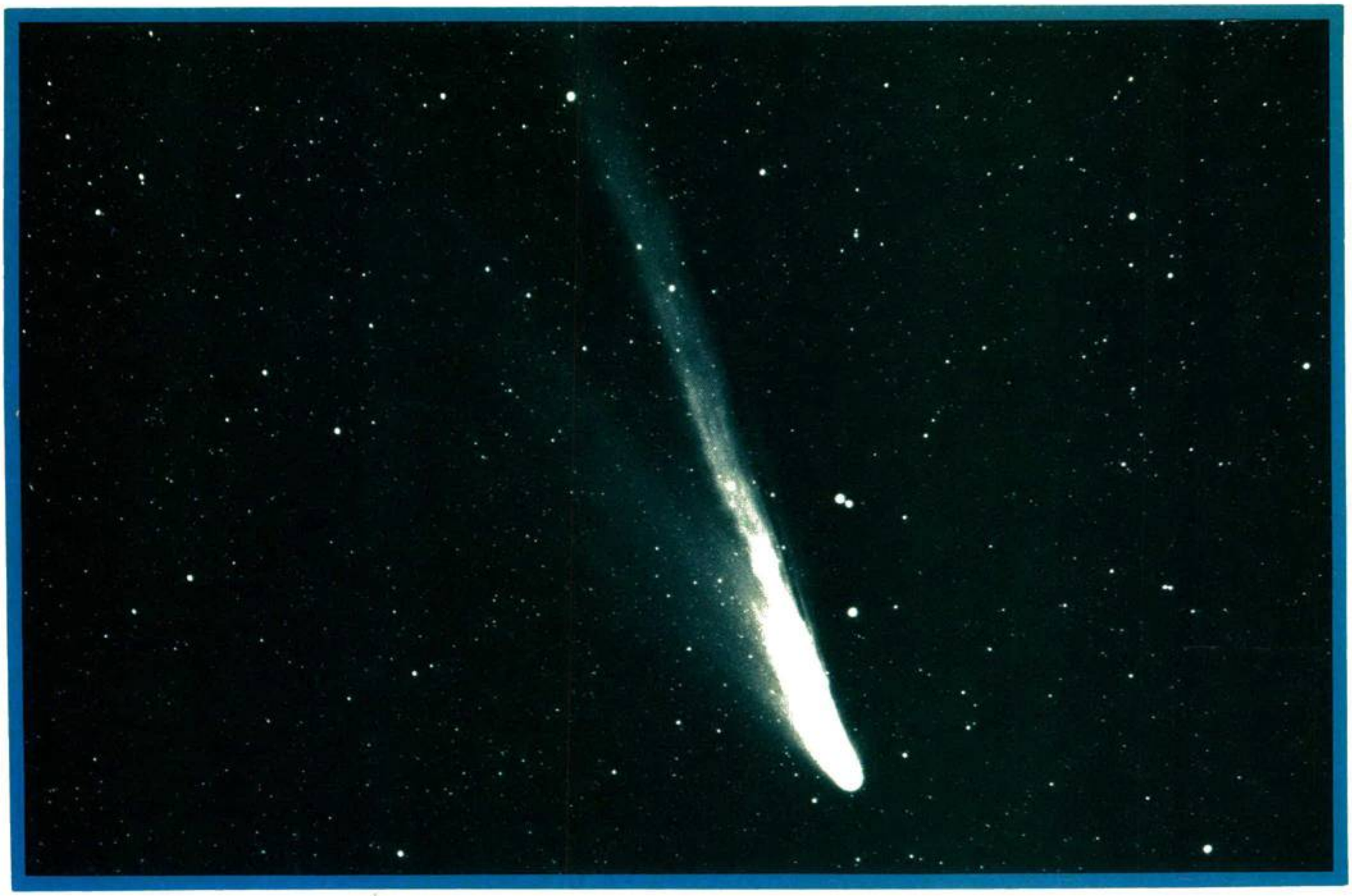
Since comets shine brightest and commonly exhibit their longest tails when close to the Sun, they are often observed in a twilit sky. Filters can darken the sky at sunrise or sunset by blocking much of the light from the atmosphere. If the background sky is reddish, for example, darken it with a light blue 80A filter; if the background is blue, use a light yellow 4 or 8 filter.

Comet Head Composition

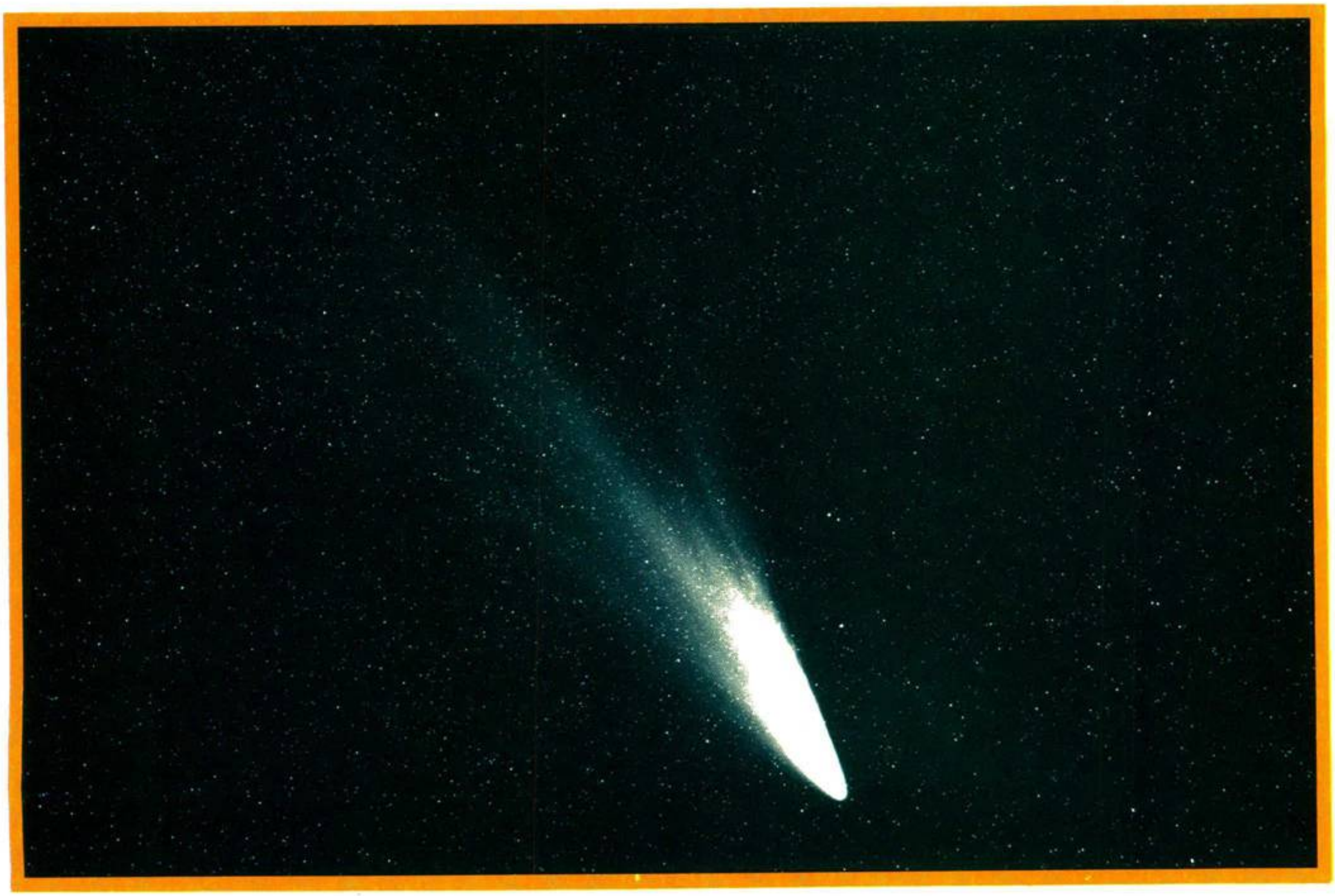
The splendor of a bright comet tail is unsurpassed. However, the delicate and changing structure that lies within the head can be the most challenging and intriguing feature of a comet. The head consists of a central, dense, usually bright nucleus surrounded by a fuzzy "atmosphere" called the coma. As almost everybody is now aware, the nucleus is really a dirty snowball — a mixture of dust and frozen gases left over from the formation of the solar system.

When the nucleus approaches the Sun, it brightens, thaws, and develops a coma. At times, bright jets of gas and dust spurt out from the nucleus to form expanding concentric envelopes, the shell structure of which is visible at medium to high magnifications. The expelled gas typically glows with a bluish light as various ice molecules break up and flouresce under the impact of ultraviolet light from the Sun. The discharged dust, on the other hand, is largely inert so it merely reflects sunlight and reddens it somewhat.

The composition of comet heads is quite variable, being either gaseous, dusty, or some ratio of both. Because its dust and



More dramatic proof of the ability of color to discriminate between the gas and dust features in a comet would be hard to find. The above photo was taken with a blue-sensitive emulsion (IIa-O) and primarily shows the straight gas tail. Taken a few minutes earlier, the yellow-light photo below (IIa-D and a Wratten 12 filter) "turns off" the gas tail and displays the dust tail. Note how star brightnesses are also affected. These Comet West photos were taken on March 13, 1976, by Ronald Royer and Steve Padilla.



gas are largely intermingled, the head of a comet often shines in both red and blue light simultaneously. The resulting magenta hue can be enhanced with a Wratten 30 filter. Bright jets of gas show up best in blue light while dusty ejecta are seen best in yellow light.

The coma usually appears smaller in yellow or orange light and larger in violet or blue light. This is due to the presence of violet cyanogen emission and blue-green carbon emission. (Cyanogen also emits some red light.) If ionized ammonia (NH_2) is abundant, it may dominate the red spectral region and the coma will appear slightly reddish or magenta. Sodium emission shows best in yellow light, as does sunlight reflected from dust particles.

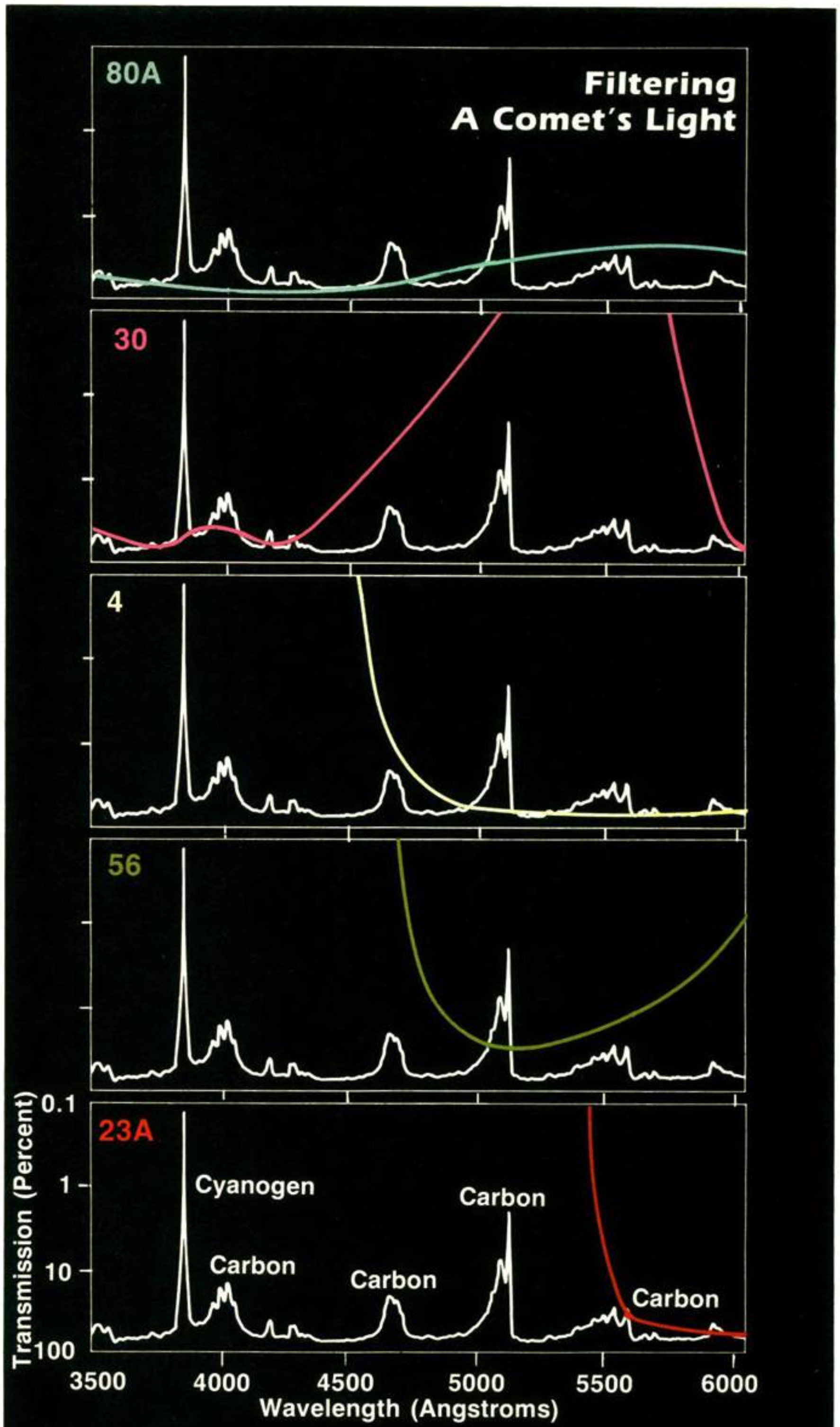
Comet Tail Structure

Naturally, these same filter techniques work with comet tails. The type I tail is a gas or ion tail containing, among other things, molecular ions of carbon monoxide and dioxide, calcium, nitrogen, and sometimes elemental sodium. Like a cosmic flag waving in the solar wind, a comet's ion tail always points directly away from the Sun regardless of what direction the comet is moving. The ion tail exhibits changing structure during the comet's active phase when it swings close to the Sun. The gases in a type I tail absorb sunlight and re-emit it at a characteristic wavelength or color that is unique to the individual gas.

Gas tails usually show best through a light blue 82A or 80A filter because these match the emission from carbon monoxide, often the strongest single emitter. Depending on what the comet does, you may see bright spikes, jets, tail spines, and rays developing at the comet's head and flowing back along the tail. Bright condensations or knots and helix structures can also occur. If the orbital geometry is right, you may see a conical shadow cast by the nucleus.

A type II tail is composed of dust shining by reflected sunlight; unlike the line emission from the gas tail, it has a continuum (all-color) spectrum. Dust is discharged into the coma along with molecules of gas as the ices of the nucleus sublimate under the warming rays of the Sun. Solar radiation pressure pushes the dust away from the Sun but to a far lesser degree than the gas tail. What happens is that the comet, in following its orbital path, runs away from the dust it sheds. The result is a broadly curving dust tail that spreads out in the comet's orbital plane.

Type II tails appear yellow or reddish and usually display less structure than gas tails, though there are interesting exceptions. On occasion, the dust tail shows a banded or rayed structure produced by intermittent dust "explosions" or outbursts from the nucleus. The filters to use for studying structure in the dust tail are a yellow 4 or 8, an orange 21, or a light red 23A.

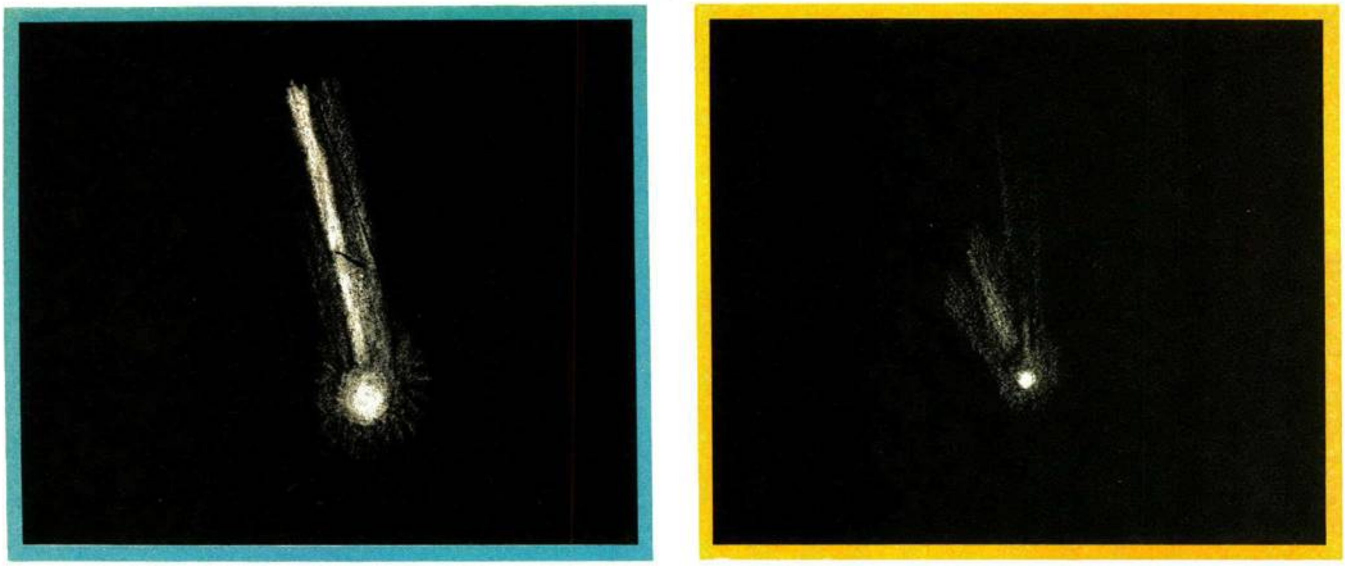


Superimposed on a spectrum of Comet Encke (from the work of Hyron Sprinrad) are transmission curves for five of the Kodak Wratten filters mentioned in this article. The comet spectrum runs from 3500 Angstroms in the blue (at left edge) to 6000 Angstroms in the orange (right edge); the main emission lines in the comet are labeled.

The higher a filter curve rises, the more light it blocks. Thus a red filter such as the 23A is opaque to all light bluer than about 5600 Angstroms, and the blue 30 filter transmits light primarily in the 3500 to 4500 Angstrom range.

All these filters are available from Kodak through photo stores. In the 2-inch square size (the smallest available), prices run as follows: Wratten 4, 8, 23A, 30, 80A, and 82A cost $7.55 each. The 56 and 58 filters are $15.40 each. (In the 3-inch square size, the prices are $11.05 and $23.11, respectively.)

These are *list* prices, however. Most photo stores offer discounts, so it will pay to shop around. Also remember that since a 2-inch gel is probably larger than you need, you can lower the price significantly by finding fellow comet-watchers to share the cost.



These sketches of Halley's Comet were made by the author on December 6, 1985, with a white pastel crayon on black construction paper. The sketch at left was made using Wratten 80A and 82A blue filters; the sketch on the right, with a Wratten 4 yellow filter.

Many comets display both types of tail clearly, thanks to the sorting effects of sunlight and orbital motion that separate the gases from the dust particles. The result is that usually the farther from the head of a comet you look, the farther apart the two tails appear. You should bear in mind, however, that the apparent separation depends critically on the Sun-Earth-comet viewing geometry, which can optically merge the two and, if the perspective is right, even create a spike that appears to extend toward the Sun.

Visually separating the gas and dust tails by their color is a lot easier if you mount a small piece of light yellow 4 and light blue 80A gel filter side by side in the same glass slide mount. Hold the paired filters over the eyepiece and look through one, then the other, shifting your gaze from the blue to the yellow and back again.

Because the composition of comets is unpredictable, so too is their behavior, color, and brightness. Indeed, a comet's structure and spectral emission can vary within a matter of hours. Consequently, if you observe systematically each clear night using light blue, green, yellow, orange, and magenta filters, you'll have a good chance of spotting significant changes. Make sketches that show how the head and inner parts of the tail look as seen through each color filter, and note which filters give the greatest effect.

Photographing Comets

Visual observations are easy, but detailed studies of comets' physical properties call for photography, particularly filtered black and white photography. A photo taken using one color filter can be compared to a photo made with a different filter to identify a comet's features and study the changes in structure and brightness. Photography can also accurately record a comet's tail length and direction.

This isn't the place for a full how-to on comet astrophotography, but here are some hints. Piggybacking the camera on an equatorial is the easiest way to get wide-field shots of a comet. Use filters that screw in over the lens aperture or get a clamp-on filter holder (such as that made by Cokin) and use gels.

If you are trying to photograph structure in a comet head, you'll need a larger image scale than even a telephoto lens provides. Put the camera at prime focus and guide on the nucleus. Although some camera/telescope adapters enable you to screw a filter in directly (if you have one of the right size), many observers will find it necessary to use tape to hold filters in the light path.

All filters rob light from the subject to some degree, and filter factors devised for daylight scenes and colors don't translate very well into recommended exposures for comet photos. But in practice the differences won't matter much since you're not trying to take one single perfect photo of a comet. In fact, what you want is a series of photos with roughly double the exposure on each succeeding frame (5, 10, 30 seconds, 1, 2, 5, 10, 30 minutes, and 1 hour); this will capture nearly everything possible. Run this full series on a comet using each of the main filters.

When you print the negatives, make the prints all to the same scale so you can compare them directly. (Keep accurate records!) It's also possible to take a series of equal-time exposures and produce a composite (integrated) print from them. Compositing increases the definition and contrast of fine head structure while decreasing the effect of film grain, though if your film is hypersensitized Tech Pan, grain won't pose much of a problem.

Unfiltered color photography also offers a lot even though its use is primarily aesthetic. Color photographs of Comet West from a decade ago, however, clearly show its straight gas tail and arcing dust tail with their colors readily apparent.

Outlook for Halley

Both types of tail are expected to be visible in Halley this time around, as they were during the last apparition. In 1910, a major complication occurred: photographs showed that the gas tail was often weak or invisible, hidden as it was by the dense dust tail when the comet was closest to Earth.

The orbital geometry for this apparition indicates that although the two tails were superimposed in late 1985, the tail-viewing angle for Halley should be good in March and April 1986 with the tails well separated. Use your filters to look for daily and hourly changes in the structure of the gas tail such as bright irregularities, breaks or gaps, and smoke-ring eddies moving down the tail. All these features were seen in 1910 and should repeat on this passage.

On past apparitions, Halley observers have noted irregular night-to-night brightenings within the head. The records also tell us that the comet is brightest when its elongation from the Sun is around 20° to 30°, which will occur in April. Jets, tail spines, envelopes, and rotational structure have often been seen in the comet's head. Filters will help isolate these delicate features by their color and brightness differences.

When you think of the many ways a set of color filters can enhance your viewing pleasure, it seems silly to let the comet pass by without using them. Far from being dispensable "extras," color filters can turn your Halley watching into something truly memorable.

Charles F. Capen is senior research astronomer for the Institute of Planetary Research Observatories and is also the Mars Recorder for the Association of Lunar and Planetary Observers. He has been an active observer of comets and planets for the past four decades.

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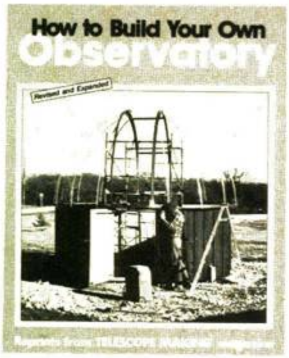

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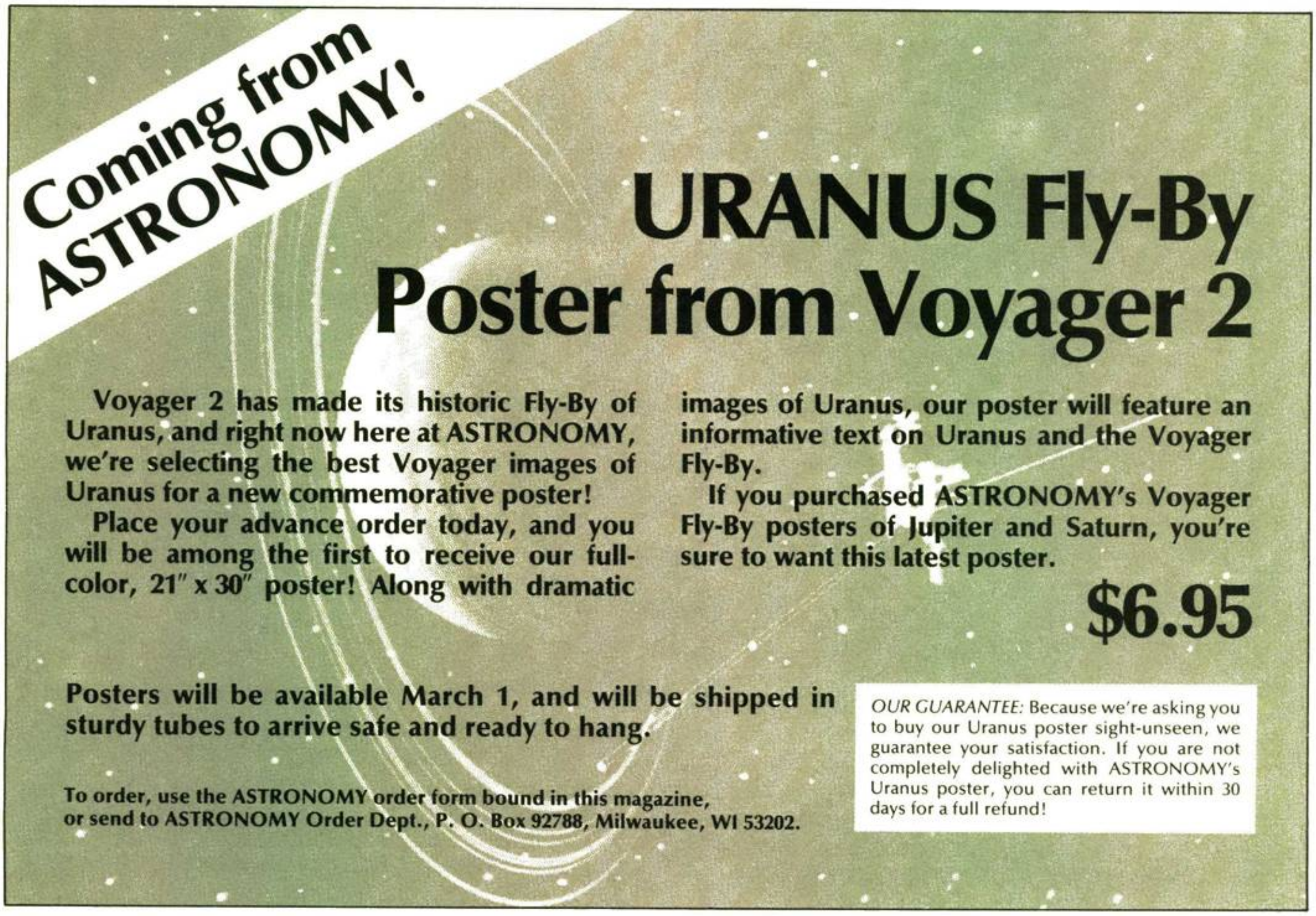

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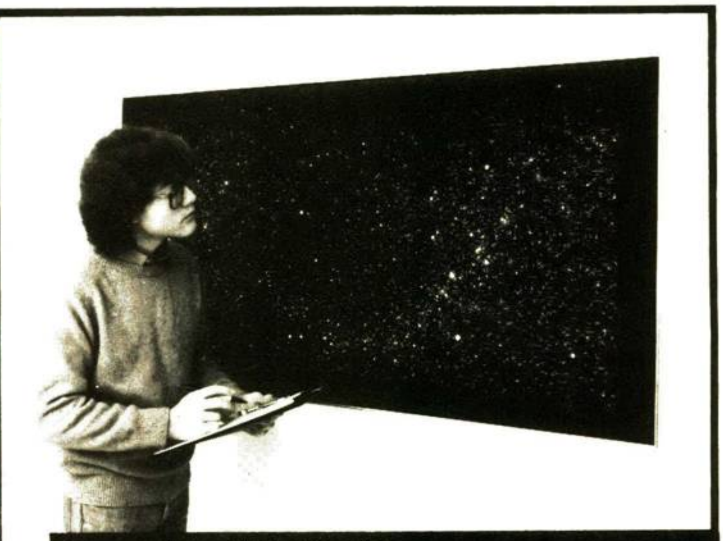

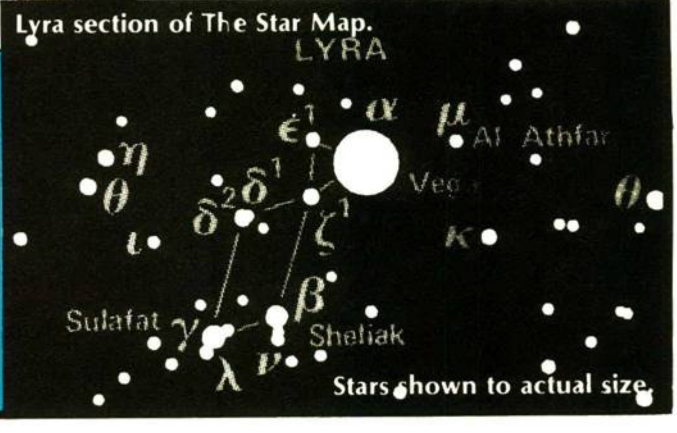

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ASTRONOMY Reviews

Star Trap Power Module

Roger W. Tuthill, Inc.
Model 1, $225

If you're heading for the hills to see Halley, you'll probably want to have electric power available at your observing site. Extension cords and cigarette-lighter converters are fine, but they keep you tied pretty closely to wherever you've parked your car. Since that often puts you alongside a road, you can be bothered by passing vehicles.

An alternative is Roger Tuthill's compact Star Trap Power Module (STPM), which has a self-contained, rechargeable battery designed to run the motor of your clock drive. This means you can set up your equipment just about anywhere. (In the southern hemisphere, though, you'll have to modify your clock drive to run in reverse.)

But the STPM is more than a power source: it converts to a drive corrector by adding a small hand-control paddle. Tuthill claims that the STPM can run a single-motor telescope for up to 10 hours without recharging, depending upon the type of scope. Eight hours or so is probably more realistic, based upon my tests; recharging takes 10 hours.

The STPM easily powered my fork-mounted 4-inch and 5-inch SCT's for slightly over eight hours each. It did not do so well with my much heavier 4-inch f/15 refractor on a German equatorial mount. I quickly found that to get the longest running time from a single charge I had to balance the scope in R.A. so that upon releasing the clutch, the scope fell gently toward the west of its own accord. The motor is then regulating the speed of the scope's fall rather than driving it.

I tested the STPM on cold New England nights and several times in hot, humid areas of central Florida. Neither environment affected the module's performance as long as I kept it fully charged.

The STPM comes in two models. Model 1 (the unit I tested) is a separate console for use with nearly any commercial scope motor. The control panel contains a socket for a special declination motor that Tuthill can furnish for those who want dual-axis drive correction. In addition, you'll find a phone jack for the optional hand control paddle, a power potentiometer, an on/off switch, a red LED (it blinks to warn you that the STPM must be recharged), a 12-volt recharging socket, and a green LED that glows when the unit has been fully recharged. Model 1 also has a separate AC socket to attach the cord from your scope's clock drive motor.

The instructions were clear and straightforward, but if you're like me you'll be tempted to hook up the STPM without carefully reading them. Don't. Read the instructions carefully *before* you begin or you'll void the warranty. *Don Trombino.*

4-inch f/6 Apochromatic Refractor

Optical tube assembly, $795
Astro-Physics Corp.
Rockford, IL

Very rarely does a new product immediately impress me as truly outstanding, but the recently-introduced line of apochromatic refractors from Astro-Physics has succeeded in doing so. I had nearly a month to put their 4-inch f/6 apochromatic refractor instrument through its paces, not only by testing it on close double stars and planets, but also by testing it against a precision optical test flat using the Foucault and Ronchi tests. Overall, the lens rates as one of the finest — if not *the* finest — commercial objectives I have had the opportunity to test. The telescope is an outstandingly versatile instrument for the beginner or advanced amateur.

The telescope that I evaluated (unfortunately, Astro-Physics apparently does not put serial numbers on its telescopes) was optimized for photographic work, so the objective had its shortest focus in blue light. Although visually corrected lenses usually have their shortest focus in the yellow-green part of the spectrum, the instrument had sufficiently good color correction for critical work at high magnification.

Using a 4mm eyepiece, the apochromat provided a superb view of Saturn. It split the unequal double star Epsilon Bootis as cleanly as I have ever seen it split with any 4-inch telescope, and better than I have seen many 6-inchers manage. Epsilon Lyrae was so perfectly and clearly split that it looked like two tiny pairs of diamonds resting on black velvet. With a 9mm Nagler eyepiece, the view was stunning. Stars were rendered absolutely crisp and sharp to the extreme edge of the field, making the rich starfields in Cygnus impressive even from my rather badly light-polluted backyard. With a 32mm Erfle, the instrument could act as its own finder or as an RFT for sweeping the Milky Way. Few instruments offer such low to high power versatility, and no other I have seen even comes close to the Astro-Physics apochromat in combined versatility and optical quality.

I star-tested the apochromat on the Astro-Physics model 706 equatorial mount. This mount is intended for larger instruments in the Astro-Physics line, so it was great for the compact 10-pound 4-incher. The pleasure of testing a fine optical system was doubled by the ease of using this rock-solid equatorial mount. The out-of-focus star image was very nearly the same inside and outside focus, testifying to excellent centering and overall correction of the lens. However, testing on a bright star (Vega) *just* inside focus, the image had a slight reddish halo; outside focus it had a pale greenish fringe. The color fringes disappeared at the best focus. These rather subtle effects just inside and outside focus were the only visible remnants of chromatic aberration which destroys fine definition in a conventional 4-inch f/6 achromat.

After critical star-testing, I tested the apochromat against a high-precision optical flat (i.e., in autocollimation) in blue, green, and red light using both the Foucault and Ronchi test. These tests revealed weak spherochromatism, accounting for the color fringes seen in the star test. Although hardly enough to harm the image, the objective appeared slightly undercorrected in red light; in blue light it was slightly overcorrected. In green, the Ronchi bands were straight, indicating no residual spherical aberration. The Foucault test in autocollimation revealed some faint zones in the figure of the lens, but it was free of significant optical defects. Very few commercial optical systems stand up this well to critical examination.

In sum, the 4-inch f/6 apochromatic refractor from Astro-Physics is an outstanding value, providing unparalleled optics in a fine mechanical assembly at a price below that of its competition. As a versatile first telescope or as an advanced amateur's go-anywhere telescope, the Astro-Physics 4-inch f/6 apochromat is unsurpassed. *Richard Berry.*

How Do You Go to the Bathroom in Space?

William R. Pogue
156 pages, paperback, $4.95
Tom Doherty Associates (1985)
[Publisher's address: 810 W. 36th St., New York, NY 10018]

Despite its irreverent title, this relatively short question-and-answer paperback, written by former astronaut William Pogue, is a refreshing look at living in space by one who must certainly know a lot about the subject. Pogue, along with Gerald Carr and Edward Gibson, shares the current 84-day American record for living in space. The three astronauts set their record on the third and last Skylab flight in late 1973 and early 1974.

Pogue answers 187 questions which range from his work as a test pilot before his astronaut days to adaptation problems that he experienced after returning from Skylab.

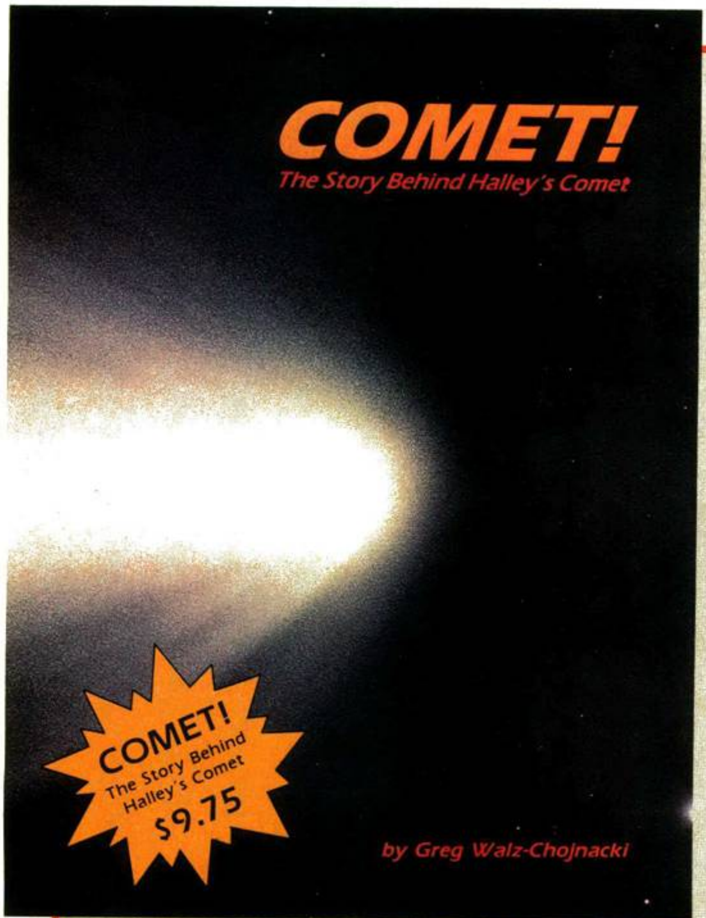
Where else can you read an astronaut's frank admission of an argument among crew members and "frequent" disagreements with people in Mission Control back on Earth? And have you heard about the astronaut who absent-mindedly put a fellow astronaut's ice cream in the food warmer while leaving his steak in the freezer? As Pogue acknowledges, "there wasn't too much conversation at dinner that night."

Of course, the title question about using the bathroom is also answered — perhaps to a greater length than most questions in the book. Other more intriguing bits of information abound. For example, Pogue notes a peculiar physiological effect he experienced for a week after his return from space. Whenever he tried to walk, he would involuntarily drift to the right. Twice, he said, he drove off the right side of the road. He didn't tell doctors, however, because he didn't want to become a "guinea pig for more medical tests."

Another interesting aspect of the Skylab mission involved what the astronauts considered to be up or down. While most of the time it wasn't a concern, Pogue describes his amusement as one of his colleagues, while looking out the window at Earth, would "always move his head or body around until his head was 'up' facing the horizon."

The view of Earth from Skylab was spectacular. Once, Pogue became so mesmerized by it that he became careless. This happened on a spacewalk when Pogue accompanied Carr, who was doing a one-man repair job. Pogue moved away from his prescribed position to a place where he had a much better view of Earth. He was suddenly directed by Gibson, who was inside Skylab and having trouble controlling the gyros that stabilized the spacecraft, to return to his original work station. Pogue then realized that at his sightseeing position, "used" air venting from his spacesuit (a normal procedure) was having "the same effect as a small rocket engine and was tending to roll the entire 80-ton space station."

Besides interesting anecdotes, a welcome surprise is the appendices and bibliography. One appendix lists various physiological effects of space flight, while another lists addresses to write to for more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The author is associate editor of **Odyssey**, the young people's magazine of astronomy and outer space — from AstroMedia, of course!

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information and photos dealing with the space program.

While the question-and-answer format of the text works well, the answers usually seem aimed at a somewhat juvenile audience. And while extremely interesting, the responses often leave you begging for additional comments and information. They're almost titillating. Let's hope Pogue decides to write an expanded, in-depth book that fleshes out the interesting tidbits. I want more. *Ray Grasshoff.*

The Soul of the Night
Chet Raymo
208 pages, hardcover, $15.95
Simon & Schuster (1985)

Besides this work and two books on geology, Raymo is the author of *365 Starry Nights*, an astronomy book for beginners. Here he uses astronomy as a framework for exploring some of the large philosophical questions posed by the science. Cast in the form of 20 short, meditative essays, these speculations run a wide range: one links the overwintering of Mourning Cloak butterflies to the many elements a given atom can dwell in during the history of the universe. Another relates how the ideas of a stonecutter acquaintance (that matter is solid, enduring) contrast with those of particle physicists. A third essay passes from a night spent watching the Perseids to the "dark constellations" formed by the Peruvian Indians to the vast quantities of dark matter filling the universe — the "missing mass" problem. The book also features many striking wood engravings by Michael McCurdy.

The Astronomy of Levi ben Gerson
Bernard R. Goldstein
310 pages, hardcover, $68
Springer-Verlag (1985)

Levi ben Gerson (1288-1344) was a medieval astronomer who lived in Holland and France, and wrote in Hebrew. His astronomical writings, chiefly a critical commentary on Ptolemy, form a small part of a much larger work on religious philosophy. In this book, Goldstein places Levi and his astronomical work into context, and provides both an English translation and the original Hebrew text.

Nemesis: the Death-Star and Other Theories of Mass Extinction
Donald Goldsmith
192 pages, hardcover, $15.95
Walker and Company (1985)

Theoretical "nuclear winter" studies show how easy it could be for comet impacts to wipe out, or at least greatly deplete, large populations of living things. The problem of linking the theoretical possibility to the actual periodic extinctions found in the geological record isn't easy, however. Goldsmith, an astronomer who teaches at UC-Berkeley, explores the controversial Nemesis theory in which a hypothetical companion star to the Sun perturbs large numbers of comets out of their parking orbits in the Oort Cloud, and sends them raining down on the inner solar system with disastrous effects on Earth.

Celestial Mechanics
Laurence G. Taff
520 pages, hardcover, $45
John Wiley & Sons (1985)

As the subtitle "A Computational Guide for the Practitioner" hints, this is a practical book, not one that expounds theoretical principles. The topics covered include the two-body problem, coordinate and time systems, corrections to coordinates, orbit determinations, perturbations, stellar dynamics, and binary star systems. Besides being a manual for professional scientists, it is also intended as a textbook for college-level courses and contains many examples and problems.

Catalogue of Meteorites, 4th Edition
A.L. Graham, A.W.R. Bevan, and
R. Hutchison, eds.
460 pages, hardcover, $50
University of Arizona Press (1985)

This list gives name, place of finding (or impact), a brief description of chemical content with citations to original literature, weight, present owner, and, if appropriate, specimen number in the British Museum's collection for some 2,784 meteorites. Ancillary tables provide statistical breakdowns (for example, of the 15 meteorites from Pakistan, 14 were observed to fall and one is rated "doubtful"; 13 of these specimens are in the British Museum). There is also a catalogue of authenticated, doubtful, and discredited meteorite craters.

Masks of the Universe
Edward Harrison
306 pages, hardcover, $18.95
Macmillan (1985)

"The theme of this book is that the universe in which we live, or think we live, is a universe largely of our own making. The underlying idea rests on the distinction between *Universe* and *universes*." Capital-U Universe is the real, albeit unknowable, thing: ". . . we are a part or an aspect of the Universe experiencing and thinking about itself." The small-u universes are the models, or the "masks" of the title, with which we rationalize human experience. Harrison first looks at past universes, describing their features and then explores our current universe, the modern physical one. In his final section, he deals with some miscellaneous topics relating to cosmology.

A First Course in General Relativity
Bernard F. Schutz
376 pages, hardcover, $54.50
Cambridge University Press (1985)

An introductory textbook in relativity which uses mathematical problems to teach special and general relativistic ideas. Included are sections on tensor analysis, vector analysis, fluids, curved space-time, Einstein's field equations, Schwarzschild geometry and black holes, and cosmology.

Comets, Meteors, and Asteroids
Stan Gibilisco
208 pages, paperback, $12.95
TAB Books (1985)

This book is a survey of solar system astronomy as it applies to the objects mentioned in the title.

Star Mark
5" x 8.3" plastic sheet, no price given
Notation Systems (1985)
[Publisher's address: 10 Riverside Dr.,
Binghamton, NY 13905]

The *Star Mark* is a sheet of plastic frosted on one side; it is meant to be overlain on a photo or drawing. You make annotations on the frosted plastic and thereby keep your original print free of marks. Around the edges are places to log such data as date and time of exposure, film used, telescope, f/ratio, object's motion, etc.

Permanent Presence — Making It Work
Ivan Bekey, ed.
171 pages, hardcover, $40;
paperback, $30
American Astronautical Society (1985)

The 22nd Goddard Memorial Symposium was devoted to "offering an early look at a Space Station program including missions, architecture and infrastructure, productivity, and technology." Although the book is aimed at professional engineers and technologists, any die-hard space buff will find the contents accessible.

Building the Universe
Christine Sutton, ed.
361 pages, hardcover, $24.95
Basil Blackwell (1985)

A compendium of articles from the English journal *New Scientist*, this guide covers such topics as the birth of nuclear physics, quarks, the search for gluons, holograms, Higgs bosons, the electromagnetic force between particles, and various other subjects in particle physics.

The Exploding Suns
Isaac Asimov
276 pages, hardcover, $18.95
E.P. Dutton (1985)

In his 310th book, Asimov explores the characteristics of supernovae. After briefing the reader on various types of stars, he details S Andromedae — the first observed extragalactic supernova — the Crab Nebula, and the two broad types of exploding stars.

Mathematics and the Search for Knowledge
Morris Kline
257 pages, hardcover, $19.95
Oxford University Press (1985)

Mathematics never lies far from any investigation of the material world. This popular-level survey touches on much of astronomy including the world-picture of the Greeks, the theories of Copernicus and Kepler, Newton and gravitation, and finally relativity and cosmology.

The MK Process and Stellar Classification
Robert F. Garrison, ed.
423 pages, hardcover, $45; paperback, $25
David Dunlap Observatory (1984)
[Publisher's address: Box 360, Richmond Hill, Ontario, Canada L4C 4Y6]

Classifying stars is far more than just a tidy-minded creating and filling of astronomical pigeonholes. It forces astronomers to confront, and use, all they know of the ways stars come into being, live their lives, and change form. This is a reprint of the papers given at a conference held at the University of Toronto in June 1983; it contains detailed reviews of the state of the art of stellar classification, and presents an approach to the subject which can be used at many different wavelengths besides the optical (for which the original MK system was developed).

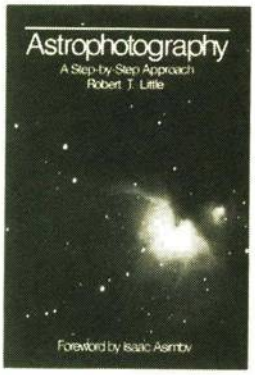
High Energy Transients in Astrophysics
Stanford E. Woosley, ed.
714 pages, hardcover, no price given
American Institute of Physics (1984)

High energy transients are the signatures of some of the most intriguing objects in the astrophysical beastiary — compact X-ray sources, gamma-ray bursters, neutron stars, interacting binaries, and the like. This volume reprints the 74 papers given at a professional conference held at UC-Santa Cruz in July 1983.

Take Halley's Home

Astrophotography: A Step-by-Step Approach

Robert T. Little, Bausch & Lomb
Foreword by Isaac Asimov



Published in time to capture Halley's Comet, *Astrophotography* features everything the beginner needs to know to produce superb photographs of the skies. This lavish, full color guide takes the reader one step at a time from the basic techniques — with and without a telescope — to deep-sky and high-power photography.

Emphasizing the use of modern color films, amateur astrophotography pioneer Robert Little shows how to take spectacular shots of • constellations • comets and meteors • lunar and solar eclipses • Venus, Mars, Jupiter, and Saturn • nebulae, galaxies, and more. And the author's own breathtaking color photographs illustrate in stunning detail what amateurs can do by following his simple, jargon-free instructions. *A Selection of the Astronomy Book Club.*

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Edward Harrison,
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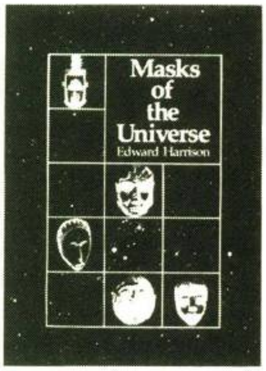

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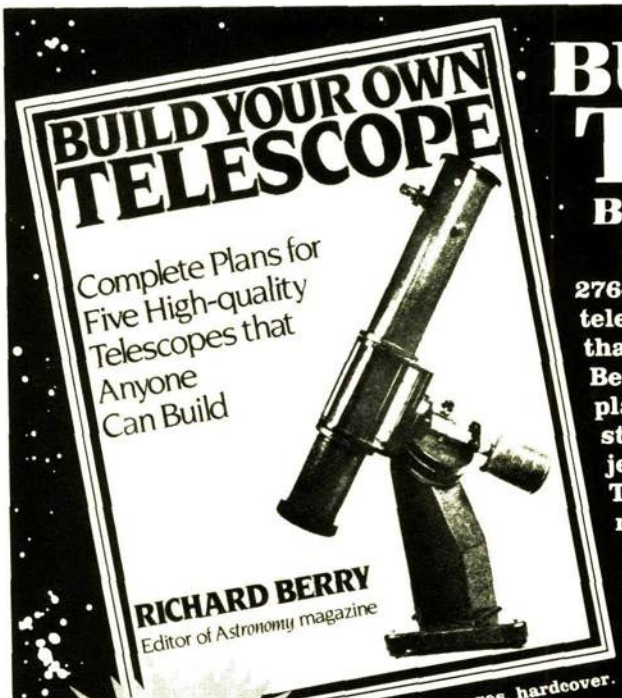

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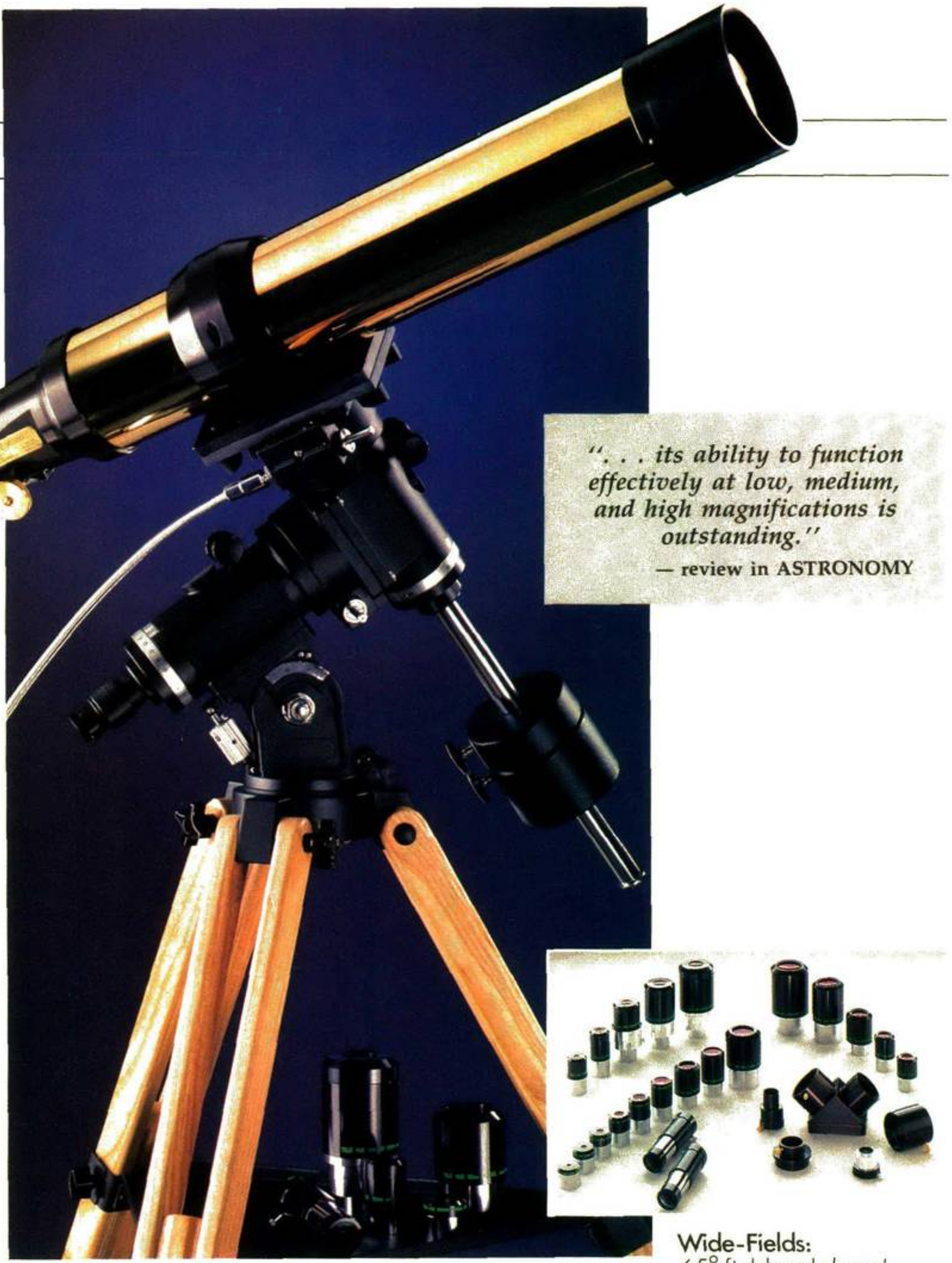

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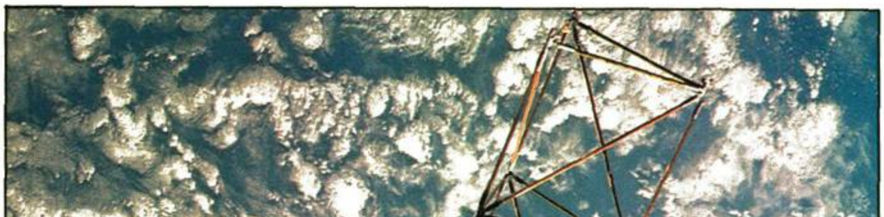
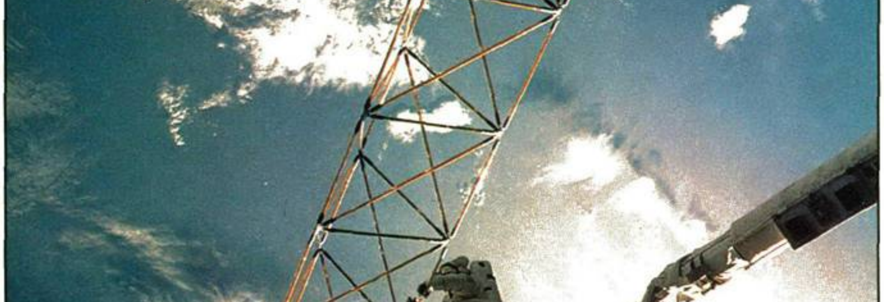


Construction techniques that will be used to build the Space Station received their first trial-run during a Shuttle mission late last year (above). Astronauts assembled this 45-foot tower by hand and maneuvered it with the aid of the Shuttle's manipulator arm. The current Space Station design (below) places crew modules betweeen two central beams and a platform holding astronomical instruments on the station's skyward end. NASA photos.



Key Decisions on Space Station Design Expected this Month

Final decisions on the shape, payload, and other key aspects of the U.S. Space Station will be made this month as the National Aeronautics and Space Administration (NASA) wrestles with a long list of options. Critical decisions on what type of scientific investigations will take place on board the station are scheduled for this summer.

A fully operational Space Station is actually an integrated system of structures and vehicles. The only currently existing piece of this system is the Space Shuttle, which will be used to carry astronauts and materials from Earth to build the rest of the system. "Space tugs" are being developed to ferry satellites and astronauts to and from the station and to service the independent orbiting platforms around the station.

The basic architecture of the Space Station has changed from the "power tower" design — a structure resembling a single electric power line tower that would support elements of the station from both ends — to a "dual-keel" design that clusters the crew and laboratory modules between two twin spines. Astronomical instruments will be mounted on a long platform attached to the skyward end of the station.

Additional instruments will be mounted on free-flying instrument carriers, which are unmanned platforms orbiting near the station. Other platforms are being developed for industrial use as well. The first such commercial platform, the Industrial Space Facility, is currently being developed by a private Houston-based firm and is expected to be placed in orbit by 1989. It is envisioned that an "industrial park in space" will eventually evolve around the Space Station.

An integral part of the station's transportation system is the "space tug," or orbital maneuvering vehicle (OMV), for which NASA has issued a request for proposals. The OMV, measuring four feet long by fifteen feet wide, will be able to retrieve satellites or platforms several hundred miles from the station and either boost them into higher orbits or return them for servicing to hangars attached to the station.

The current Space Station design allows for the possibility of future growth. The power plant can be expanded, more modules can be added, and additional hangars can be attached to service more satellites or free-flying platforms.

At present, the Space Station is in its "Phase B" stage of development, the point at which the initial overall design of the various station components is defined. In Phase B, which began last April, two or more companies are hired for a head-to-head design competition; the winner gets to build the specific item under study.

There are two companies assigned to each of the four work packages that comprise the Space Station program. Boeing Aerospace and Martin Marietta are designing the common modules, life support and propulsion systems; McDonnell Douglas and Rockwell International, the overall architecture, crew modules, and communications systems; General Electric and RCA, the platforms, servicing, and laboratory modules; and Rocketdyne and TRW, the electrical power system.

The Phase B process will also determine what specific tasks the United States' international partners will take in the station's design and construction. Components of the four work packages will be selected for completion by Japan, Canada, and the European Space Agency. Europe will handle the life sciences module outfitting; Japan will contribute the technology demonstration facilities and attached payloads controls; and Canada will develop the satellite/station servicing capability.

Phase B reaches a critical stage this month as decisions are made on the specific components and systems to be included in the Station. A systems requirement review will establish the design in terms of overall shape and will also decide between different approaches to the life support, power, and other systems. Contractors will then have until January 1987 to complete their designs. Winners will be selected and by May 1987 the final design work and construction (Phase C/D) will begin. Current plans envision the first component of the station being launched in April 1992. The station should be ready for business by April 1994.

Funding for the Space Station will be shared among each participating country. Design and construction is expected to cost $10 to 13 billion by the time the station is operational. The United States is contributing $8 billion to the project.

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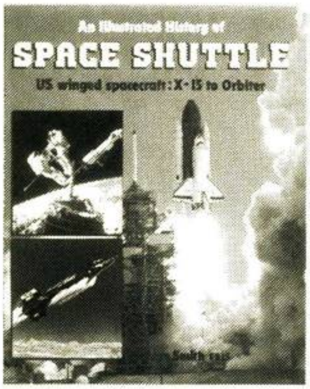
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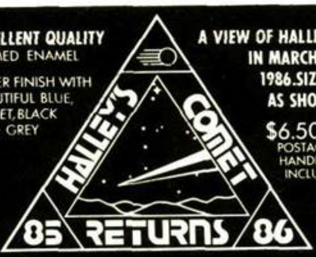

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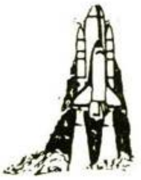

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NASA has received $361 million in fiscal 1985 and 1986 and is currently seeking $580 million for the 1987 fiscal year.

Available funding will play a big part in determining what scientific payloads will be included in the station. According to David Thompson, the science and applications advocate in NASA's Space Station office, a large number of astrophysics payloads have been tentatively selected, but he expects that only 80 percent will be funded and eventually fly.

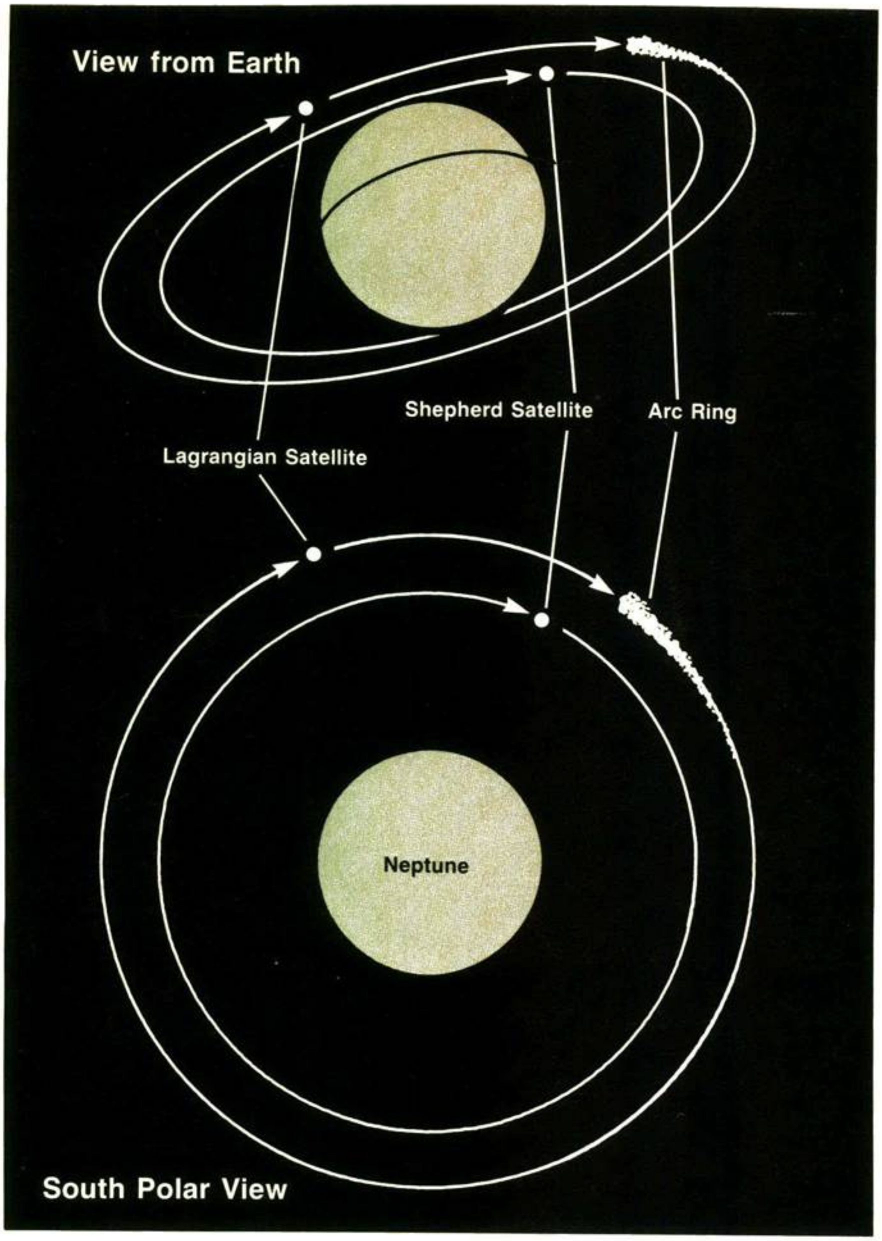
Instruments currently planned for the station platform include: the Advanced Solar Observatory, which consists of a number of instruments built around the Solar Optical Telescope that will view the Sun as a star in radio to gamma-ray frequencies; the Cosmic Ray Nuclei Experiment; the Superconducting Magnetic Facility for advanced cosmic ray studies; and the Planetary Astrometry Telescope to search for planets orbiting other stars. Several small platforms attached to the main platform would contain instruments that could be detached for periodic observations away from the station.

Instruments that would be attached to the unmanned platform are the Advanced X-Ray Astrophysics Facility for high-resolution stellar studies and the Space Infrared Telescope Facility for high-resolution studies of objects discovered by IRAS. Several other free-flying instruments, including the Hubble Space Telescope and the Gamma Ray Observatory, would be serviced by the Space Station.

"Which payloads actually are accommodated will be decided starting this summer with tenant selection," Thompson reported. This process begins with determining what percentage of available funding will be allocated to each of the categories of scientific investigations that are conducted on the station. Selection of instruments will be based on the amount of funding received.

This selection process will be closely monitored by the space science community and its representatives in the Task Force on Scientific Uses of the Space Station, a subgroup of NASA's Space and Earth Sciences Advisory Committee. The Task Force, chaired by Peter Banks of Stanford University's department of electrical engineering, is currently focusing on the international aspects of the station to make sure that facilities and experiments are shared. Another concern surrounds the development of "quick and beautiful" experiments, similar to those now launched on sounding rockets, that graduate students could fly in a timely manner.

Two members of the Task Force have been appointed as Space Station program scientists: planetary scientist David Black is at NASA headquarters and astronaut Owen Garriott is at Johnson Space Center.
Dave Dooling/Stephen Cole.



Neptune's "Ring" May Be an Incomplete Arc

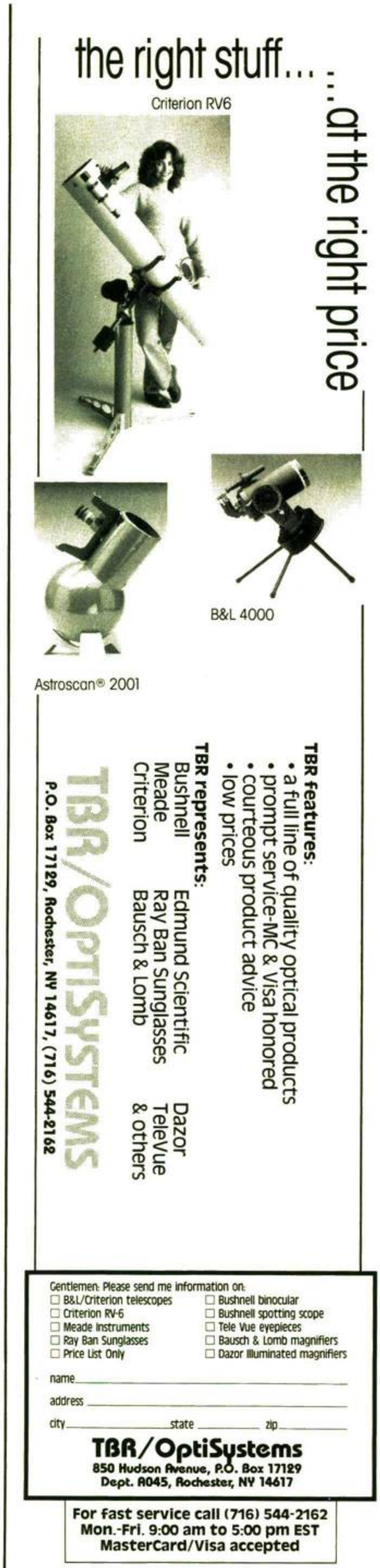
For several years, Neptune, the outermost of the Solar System's gas-giant planets, has been suspected of having an as-yet undetected ring of particles in orbit around it, a ring similar to those possessed by its cousin-worlds Jupiter, Saturn, and Uranus.

The best available data — ground-based observations of stars occulted by the planet — give clear evidence of *something* orbiting Neptune but just what that something is poses some thorny questions. Stellar occultations by Neptune in 1981 and 1984 (AstroNews, April 1985) indicate that on each of these occasions the light from two stars was partially blocked for about one second as the planet passed close to the stars' positions.

Since the starlight was never completely blocked, astronomers believe that the occulting body was not a single solid object like a moon but rather a loose "swarm" of small particles such as those found in planetary rings. What is perplexing about this neptunian "ring" is that the occultations were not symmetrical: the event apparently took place only on one side of Neptune.

In the aftermath of the 1984 observations, some astronomers have investigated the novel idea that the ring is incomplete — that it may extend only part way around the planet, leaving most of its orbit devoid of material. Some evidence exists for such a phenomenon in the saturnian rings, but how that situation relates to Neptune isn't clear. One major difficulty with this explanation is that calculations show that loose material occupying part of an orbit would spread out to fill the orbit uniformly in about three years.

Astronomer Jack Lissauer of the University of California, Santa Barbara, writing in the December 12, 1985 issue of *Nature*, advances a model to explain how a partial ring — he calls it an "arc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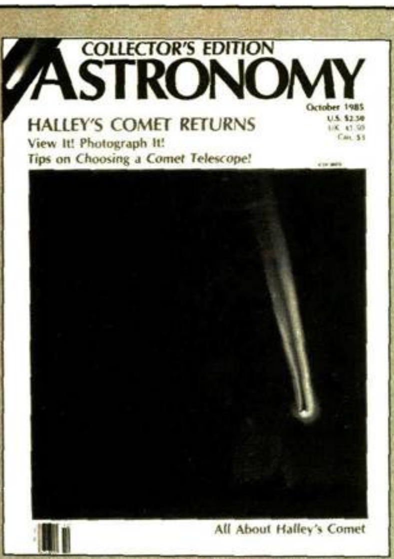

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ring" — can preserve its shape indefinitely.

To agree with the occultation observations, the ring must lie at a distance of about 67,000 kilometers from the center of Neptune and measure about 15 km wide by at least 100 km long. According to Lissauer, just such an arc ring of material could collect around Neptune if it shared a "Lagrangian orbit" with a satellite. And the arc ring could retain its lumpy identity if a second, shepherding satellite were also present and placed correctly (see diagram).

The hypothetical system would place the Lagrangian satellite and the arc ring in orbit around Neptune's equatorial plane, with the satellite 60° behind the ring. Celestial mechanics allows gravitating bodies several such stable orbital positions; for example, Jupiter has families of minor planets 60° ahead and behind it in its orbit around the Sun.

Yet any loose material orbiting Neptune at the Lagrangian point would soon drift away from the favored spot and fall in toward Neptune unless something kept it there. This is where the second satellite plays its role, rather like a dog herding a flock of errant sheep. The shepherd satellite can circle Neptune either inside or outside the orbit of the arc ring. If it orbits inside (the most likely case), the shepherd satellite will exert a periodic force outward, counteracting the inward drift of the ring particles whenever the satellite overtakes the ring. This gentle push, occurring once for each circuit of Neptune that the shepherd satellite makes, is sufficient to prevent the ring material from dispersing.

Shepherd satellites have been observed at Saturn and are thought to control the narrow rings of Uranus. The result at Neptune, claims Lissauer, is that any ring material straying from the Lagrangian point would be quietly nudged back into place.

Why haven't these satellites been observed before? Lissauer's calculations show that both satellites would be far too small (100 km to 200 km in diameter) to see with ground-based telescopes. He hopes, however, that the Space Telescope will be able to image them as should Voyager 2, if it is still working properly during its scheduled encounter with Neptune in August 1989.

NASA Mission To Bring Comets Down to Earth

When Comet Halley fades from view later this spring, it will have been observed as thoroughly as modern technology allows us to study such a distant object. To get a closer look, the comet would have to be brought into the laboratory. A mission that would accomplish just that is now being planned by NASA, according to the December 9, 1985 issue of *Aviation*

Week and Space Technology magazine.

The Multicomet Sample Return mission, scheduled for launch in November 1992, will pick up dust and gas samples from as many as four comets before rendezvousing with the Space Station in Earth orbit. The mission spacecraft will also be equipped to conduct extensive solar research.

The ten-year mission involves a trio of spacecraft that will orbit the Sun along the same circular route taken by Earth. One of the three craft will be equipped with an x-ray telescope and a coronagraph for solar imaging; the other two vehicles will carry special containers for collecting dust and gas samples as the probes pass near the cometary nuclei.

The first samples will be collected from Comet D'Arrest by one of the probes in July 1995 as the trio nears Earth for the first time. Four months later, this probe will leave its companions and ease into an orbit around the Earth where it will be retrieved by a "space tug," or orbital maneuvering vehicle (OMV). The OMV will bring the probe to the Space Station where the cometary samples will be studied.

The second probe will pass through Comet Honda-Mrkos-Pajdusakova in January 1996 and rendezvous with an OMV ten months later. Both probes will be refitted aboard the Space Station and sent out to sample Comet Giacobini-Zinner in November 1998 and Comet Tempel 2 in August 1999.

It is not expected that possible delays in construction of the Space Station will interfere with this mission since the comet probes could be kept in Earth orbit indefinitely until OMVs are ready to pick them up.

The Multicomet Sample Return mission was conceived as a follow-up to NASA's International Cometary Explorer (ICE) mission which penetrated the tail of Giacobini-Zinner in September 1985. It is also seen as a mission that will complement the comet rendezvous/penetrator mission, scheduled for 1998, which would actually land a spacecraft on the surface of Comet Tempel 2.

Astronomy Day Planned for April 19

Astronomers will be taking to the streets on April 19 as amateur and professional astronomy groups throughout the world celebrate the 13th annual Astronomy Day, an event created to "take astronomy to the people." The date of this year's Astronomy Day was chosen to coincide with one of the last weekends that Halley's Comet will shine bright enough for naked-eye observations.

Conceived by Doug Berger of the Astronomical Association of Northern California and now sponsored by astronomy organizations internationally,

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Astronomy Day was developed so that those who watch the skies regularly could share their fascination with people who have seldom or never had a chance to observe.

Astronomy Day celebrations feature telescopes set up in shopping malls, schools, parks, and even on street corners, giving thousands of people an opportunity to view the planets, Moon, nebulae, galaxies, and stars. Previous Astronomy Days have included displays on computers in astronomy, the space program, the fight against light pollution, and mirror grinding.

For local groups interested in planning activities this year, Astronomy Day coordinator Gary Tomlinson of the Astronomical League says, "You can be as sophisticated or as simple as time, manpower, and money dictate. Simply putting up a telescope for public viewing is a great way to get started."

For information on local events, contact your area astronomy club, planetarium, science museum, or college astronomy department. For information on national or regional events, write to Gary Tomlinson, Astronomy Day Coordinator, Astronomical League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503, or phone (606) 456-3985.

If your astronomy club has unique or innovative plans for Astronomy Day activities, ASTRONOMY would like to hear about them.

More Halley Hot Lines

Several newly-installed hot lines indicate that many people *still* can't get enough information about Halley's Comet. The University of Texas at Austin, the U.S. Naval Observatory in Washington, D.C., and the Planetary Society are offering new or improved services to meet the need on both a national and regional basis.

The "Austin Halley Watch" is a new service that offers callers information on Halley's current position and how to find it. The recorded message, which is updated weekly, features Deborah Byrd, executive producer of the daily astronomy radio series "Star Date." The hot line number is (512) 471-4870.

Because of the heavy volume of calls on its local hot line, the Naval Observatory has instituted a "900" number that allows anyone in the United States, Canada, or the Virgin Islands to call their "Comet Halley Hot Line," which operates through April 15. The number is (900) 410-8766.

The Planetary Society, in conjunction with ABC News, has instituted a national hot line that features Carl Sagan and ABC correspondents. Their number is (900) 410-STAR.

Callers should note that these hot line services are not toll-free.

ASTRONOMY AstroCalendar

March 14-16
Halley's Comet Festival (comet watches with telescopes provided, educational activities, children's programs), Blackwater Falls and Pipestem State Parks, West Virginia. Contact: Joe Woodfield, Halley's Comet Coordinator, Bluestone State Park, Hinton, WV 25951. Phone toll-free (800) CALL-WVA.

March 26-29
National Convention of the National Science Teachers Association, San Francisco, California. Contact: Matthew R. Murphy, NSTA, 1742 Connecticut Ave., N.W., Washington, DC 20009. Phone (202) 328-5800.

April 4-12
Halley's Comet Festival (films, children's programs, "second timers" picnic), North Bend and Pipestem State Parks, West Virginia. Contact: Joe Woodfield, Halley's Comet Coordinator, Bluestone State Park, Hinton, WV 25951. Phone toll-free (800) CALL-WVA.

April 5
Halley's Comet Watch, sponsored by the Arkansas Oklahoma Astronomical Society, Ben Geren Regional Park, Fort Smith, Arkansas. Contact: Larry Kennedy, Route 3, Box 421-Y, Pocola, OK 74902. Phone (918) 436-2204 evenings.

April 11
International Halley Day of Harmony. Contact: James B. Harris, Jr., Florida Space Week Committee, P.O. Box 291, Sharpes, FL 32959. Phone: (305) 632-9139.

April 12
40th Annual Convention of the North Central Region of the Astronomical League, sponsored by the Popular Astronomy Club, Augustana College, Rock Island, Illinois. Contact: Paul Castle, 1986 NCRAL Convention Chairman, 2535 45th St., Rock Island, IL 61201.

April 19
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, Astronomy League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

April 19
Astronomy Day Celebration and Star Party, sponsored by the Northwest Suburban Astronomers, Hoffman Estates, Illinois. Contact: John Conneely, 814 Gettysburg, Arlington Heights, IL 60004. Phone (312) 253-4735.

April 23-26
Middle Atlantic Planetarium Society Annual Spring Meeting, Wheeling, West Virginia. Contact: Steve Mitch, Benedum Natural Science Theater, Oglebay, Wheeling, WV 26003.

May 5-10
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: Carol Rodgers, 128 N. Commerce, Burleson, TX 76028.

May 9-10
Microcomputers in Physics and Astronomy, Valdosta State College, Valdosta, Georgia. Contact: Dr. Dennis Marks, Dept. of Physics, Valdosta State College, Valdosta, GA 31698.

May 16-18
Annual Meeting and Conference of the Royal Astronomical Society of New Zealand, Palmerston North, New Zealand. Contact: Noel Munford, President, Palmerston North Astronomical Society Inc., Centennial Observatory, Anzac Park, P.O. Box 398, Palmerston North, New Zealand.

May 22-25
Riverside Telescope Maker's Conference, Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92503. Phone (714) 689-6893.

May 23-26
Fifth Annual Space Development Conference, Seattle, Washington. Contact: 1986 Space Development Conference, Dept. C3, P.O. Box 30869, Greenwood Post Office, Seattle, WA 98103.

June 19-21
IAPPP Symposium on Photoelectric Photometry, Mercyhurst College, Erie, Pennsylvania. Contact: Robert C. Reisenweber, Rolling Ridge Observatory, 3621 Ridge Parkway, Erie, PA 16510. Phone (814) 899-2560.

June 22-26
168th Meeting of the American Astronomical Society (professional meeting), sponsored by Iowa State University, Ames, Iowa. Contact: AAS, 1816 Jefferson Pl., N.W., Washington, DC 20036.

June 29-July 4
International Planetarium Society Eighth Biennial Conference, Tucson, Arizona. Contact: IPS Conference Committee, Flandrau Planetarium, University of Arizona, Tucson, AZ 85721. Phone (602) 621-4515.

August 5-10
AstroCon 86 (national convention of the Astronomical League), Baltimore, Maryland. Contact: Astro-Con 86, 642 Kingston, Rd., Baltimore, MD 21220.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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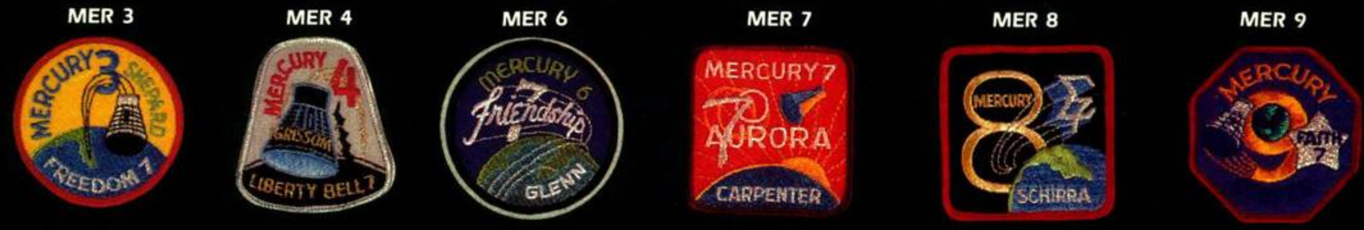
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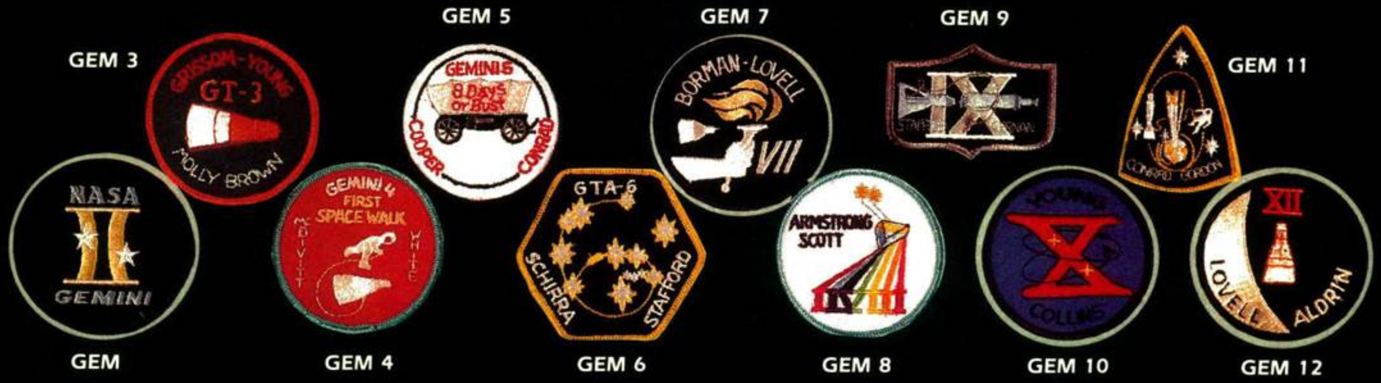
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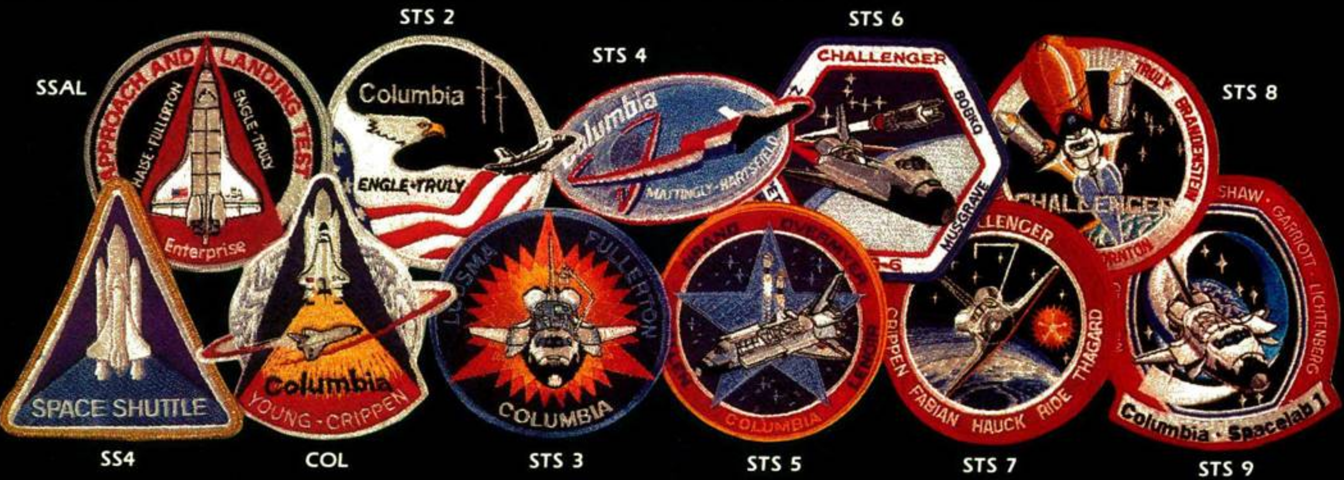
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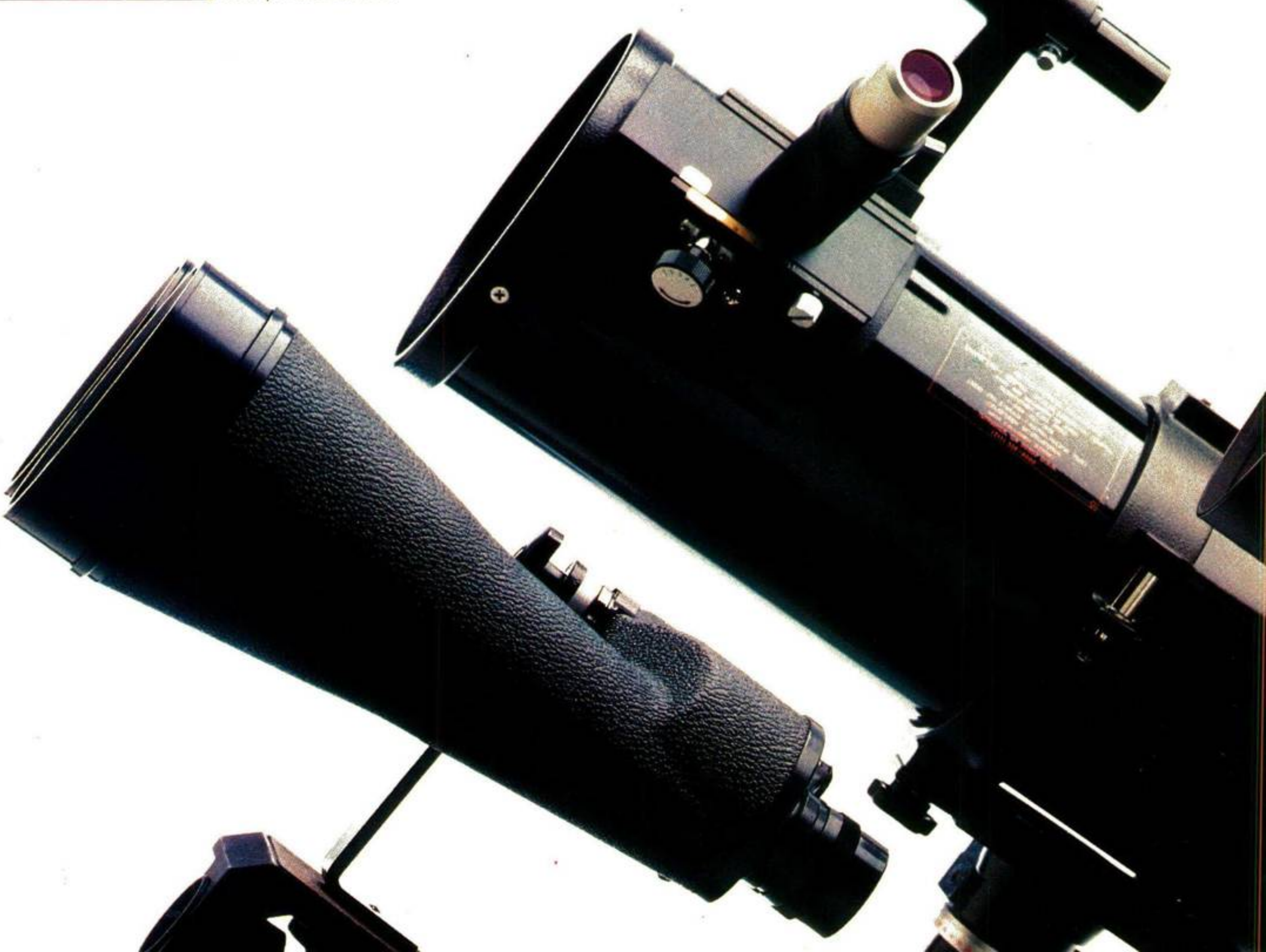

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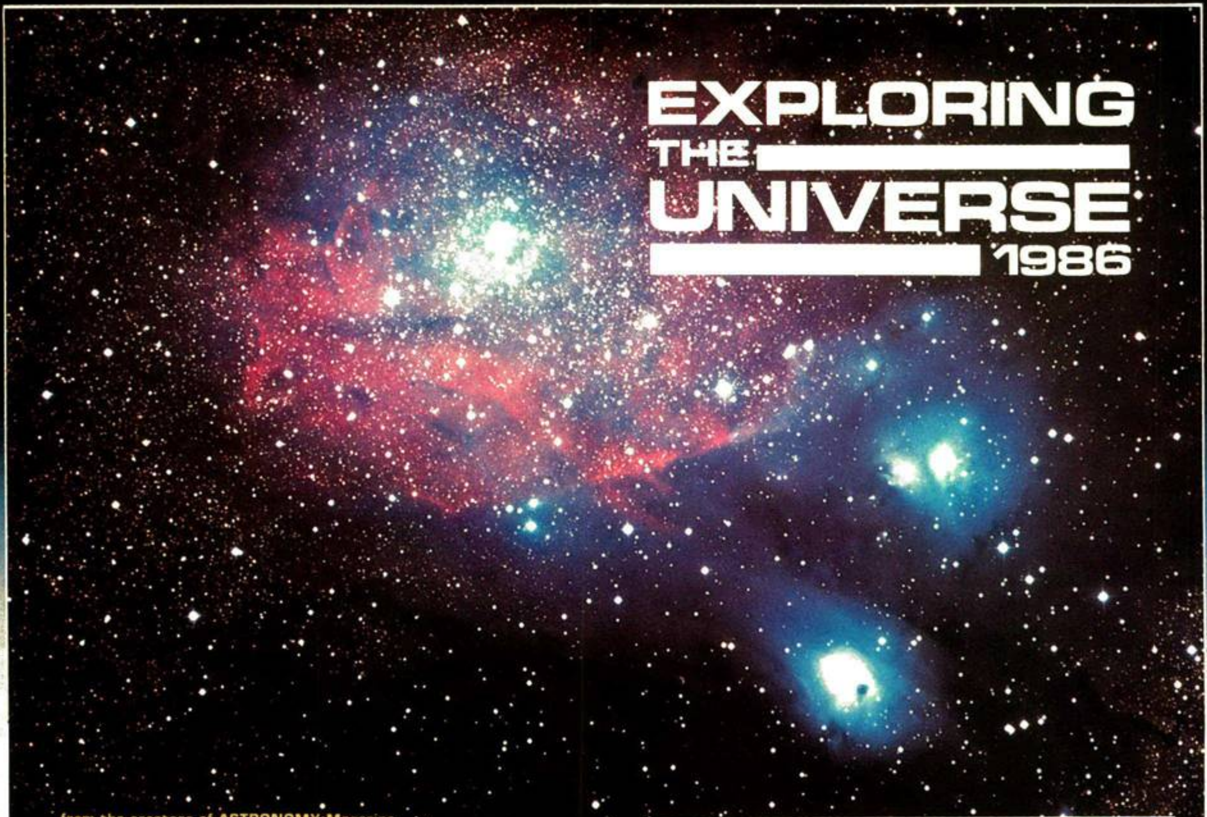

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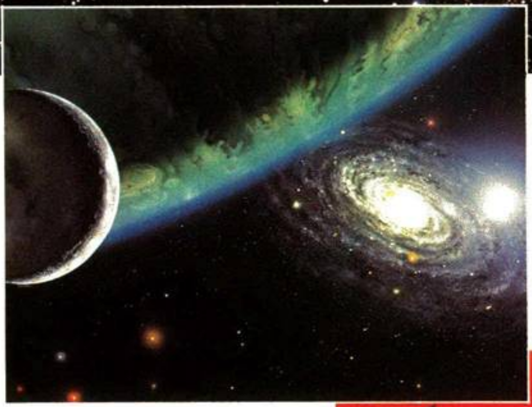

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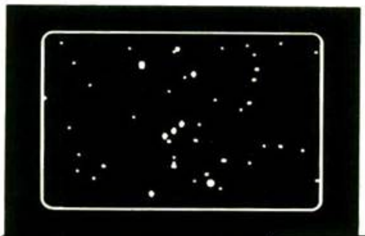

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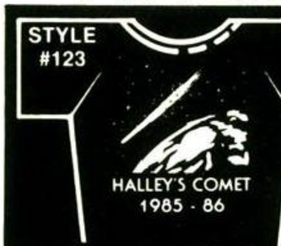

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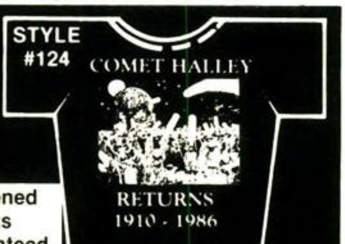

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KAO

The Airborne Assault on Comet Halley

by Humberto Campins and David K. Lynch

When Comet Halley comes calling this month, two NASA jets will be cruising high over the South Pacific to meet it. The Kuiper Airborne Observatory and the Learjet Observatory are NASA's two flying astronomical observatories. The aircraft provide stable high-altitude platforms from which to observe celestial objects at infrared wavelengths; their target this spring is Comet Halley.

The Kuiper Airborne Observatory (KAO) is a modified Lockheed C-141A Starlifter jet transport with a cruising speed of 425 knots and a maximum ceiling of over 45,000 feet. It carries a 36-inch telescope that looks out through a specially designed hole cut into the fuselage just forward of the wing. Its normal crew is two pilots, a flight engineer, three to five observatory personnel, four to eight primary experimenters, and two to four additional experimenters working in the rear of the aircraft.

The Learjet Observatory (LJO), a Learjet model 24, operates most frequently as an infrared observatory but is also used for atmospheric physics and meteorology experiments, Space Shuttle training, and radar evaluation. It carries a 12-inch telescope, which is placed into the hole that was originally the emergency exit. The usual number of people on board during a research flight is four: pilot, co-pilot, and two very cramped experimenters.

The telescopes on both jets are equipped with precision alt-azimuth mounts that point out the port side of the ship. The optical surfaces are directly exposed to the air, but the detector instruments are inside the pressurized cabin behind a small, transparent window. To prevent the air of the slipstream from buffeting the telescope, the fuselage has a screen directly ahead of the telescope cavity. This breaks up the wind blast and keeps the air in the instrument cavity relatively quiet.

Tracking on a celestial object from an airborne observatory is a tricky task that combines straightforward engineering with extraordinary piloting skill. The telescope is built to point up and down in elevation, but it has very limited motion in azimuth. To gain this other degree of freedom, the entire plane must swing from left to right. The pilot carefully flies along a predetermined curving path that keeps the target object exactly in place off the left-hand side of the aircraft. Two gyroscopes and two torque motors (one of each for each axis) fine tune the telescope's position and hold it to a few arc-seconds or better, even in moderately turbulent air. It's eerie to watch the massive telescope making sharp little jerks and realize that the telescope itself is rock steady; it's actually the entire aircraft which is drifting off target.

Besides having three times the aperture of the telescope aboard the LJO — 36 inches versus 12 inches — the KAO telescope also has an advantage in that its mirrors can be cooled. Because the temperature at typical observing altitudes is −55° F, the mirrors and support structures cool off during the flight. But since each part cools at a different rate, stresses develop that can warp the optics and degrade the image. To compensate, the ground crew seals off the telescope cavity several hours before flight time and blows cold, dry nitrogen gas through it to cool the telescope. Thus, when the observatory reaches operational altitude, the telescope is already at working temperature.

Besides improving the quality of images, precooling the optics offers a second benefit for infrared observing: lower "noise." Because the infrared emission received from a star must mix with infrared radiation emitted by the telescope mirrors themselves, cold mirrors produce a cleaner, less ambiguous signal.

Each aircraft brings a complementary set of abilities to the study of Comet Halley. Although the KAO telescope has a larger aperture, it cannot safely point as near to the Sun as can the LJO (30° minimum angle versus 15°). Thus the LJO will be able to observe the comet when it is expected to be brighter and more active. Engineering constraints severely restrict both telescopes in their elevation ranges: the KAO is limited to +35° to +72° elevations (relative to the horizon) and the LJO can only sweep from 0° to +30°. Because the telescopes cannot simply point anywhere in the sky an astronomer may want, mission designers have to take into account the declination of the target object when planning observing runs. Given Halley's location and the jets' operational ranges, the choice of "home base" latitudes for the comet missions is fairly restricted. The KAO will be stationed at a Royal Australian Air Force base near Sydney, Australia, and the LJO will fly from the Marshall Islands.

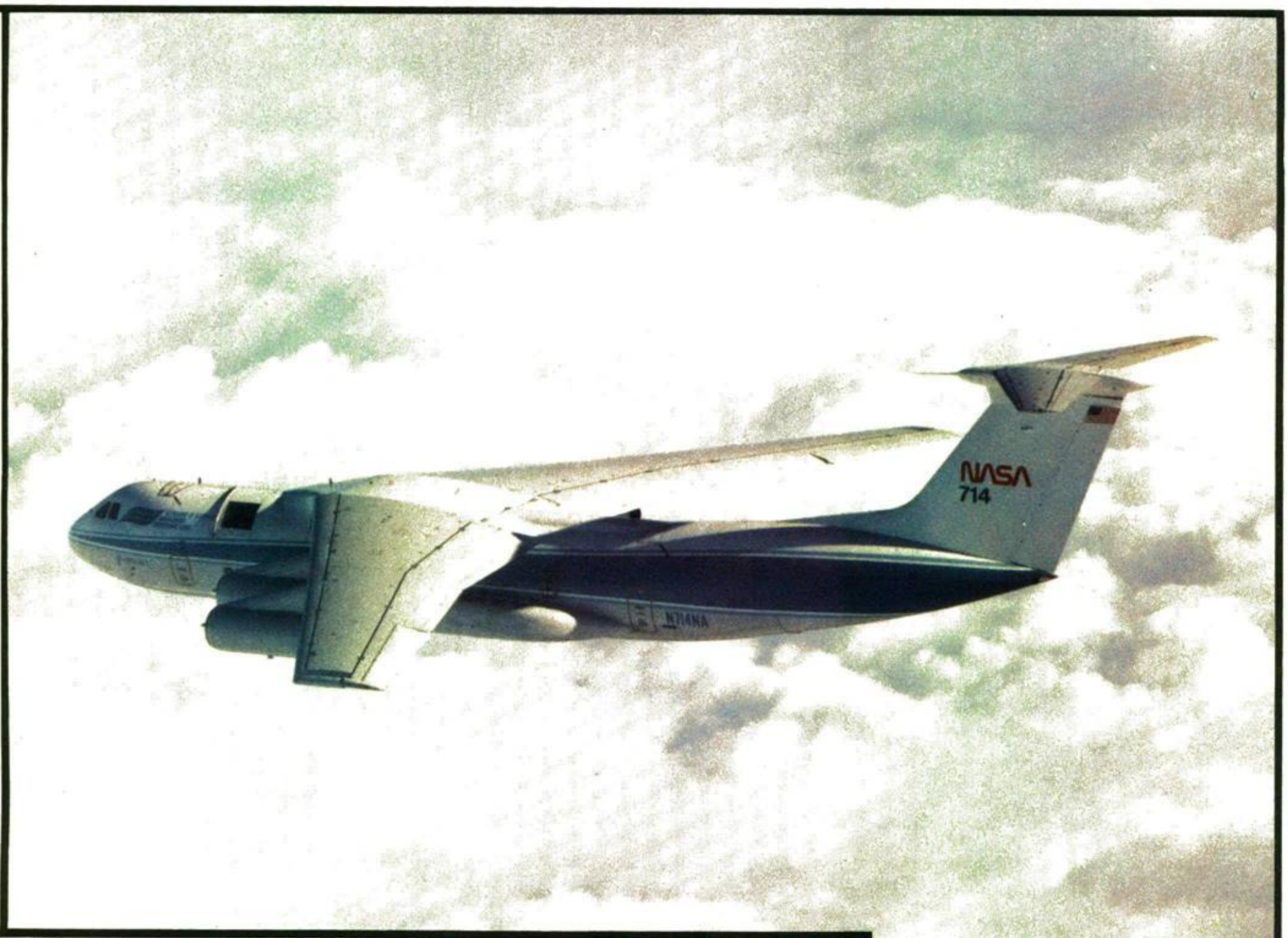
Why do astronomers need to observe at high altitudes? The answer is that our atmosphere blocks out much of the infrared spectrum. Even high-altitude ground-based observatories (such as the one atop Hawaii's 13,800-foot Mauna Kea) can see out of the atmosphere through only a few narrow infrared "windows" — regions in the spectrum where the atmosphere is partially or wholly transparent. These windows do not permit continuous spectroscopic measurements. Only by placing an instrument aboard a high-flying aircraft or into space itself can an astronomer study the full infrared spectrum.

Fortunately, the largest source of atmospheric opacity — water vapor — tends to collect in the lower atmosphere where our weather takes place. This region is called the troposphere. Above that lies the stratosphere, which is extremely dry. Each KAO or LJO flight aims for the stratosphere because infrared visibility is virtually unrestricted there.

The stratosphere can begin at altitudes as low as a few thousand feet over the polar regions or as high as 50,000 feet or more in the tropics. As weather systems come and go, its altitude changes daily. Indeed, convection turbulence and clouds can even plague flights that go as high as 45,000 feet, though luckily this doesn't happen often.

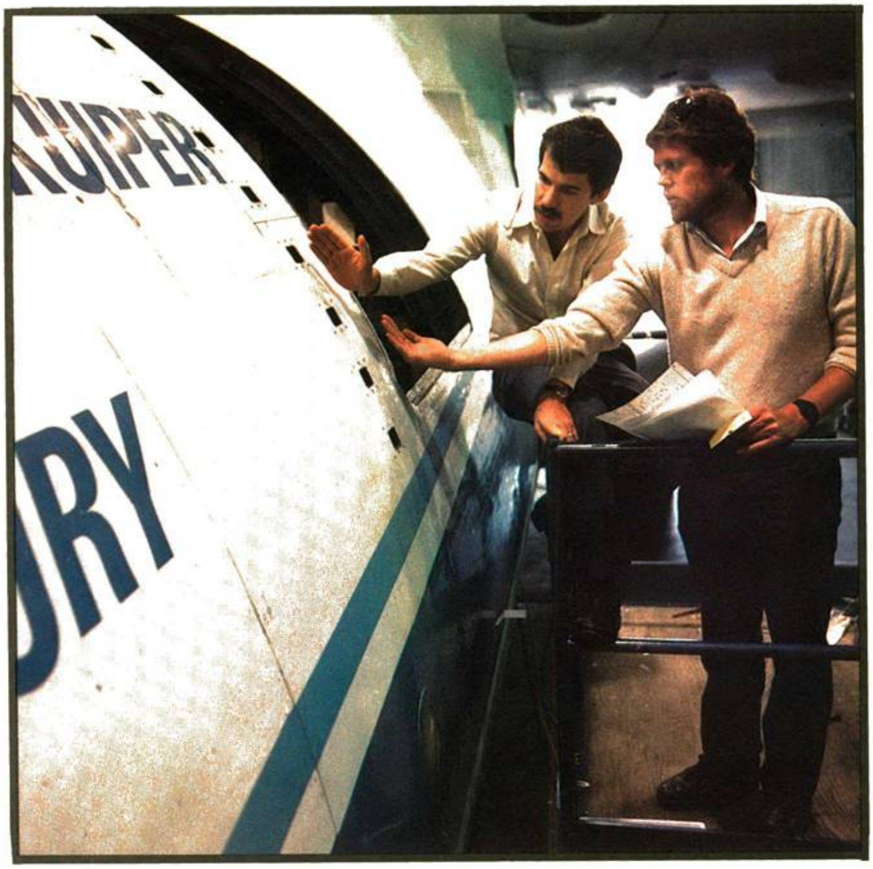
Because Australia lies in the middle southern latitudes where the stratosphere begins at a lower altitude than in the tropics, the KAO astronomers stand a good chance of reaching the stratosphere for their Halley flights. On the other hand, the LJO will probably never get above the troposphere because of the

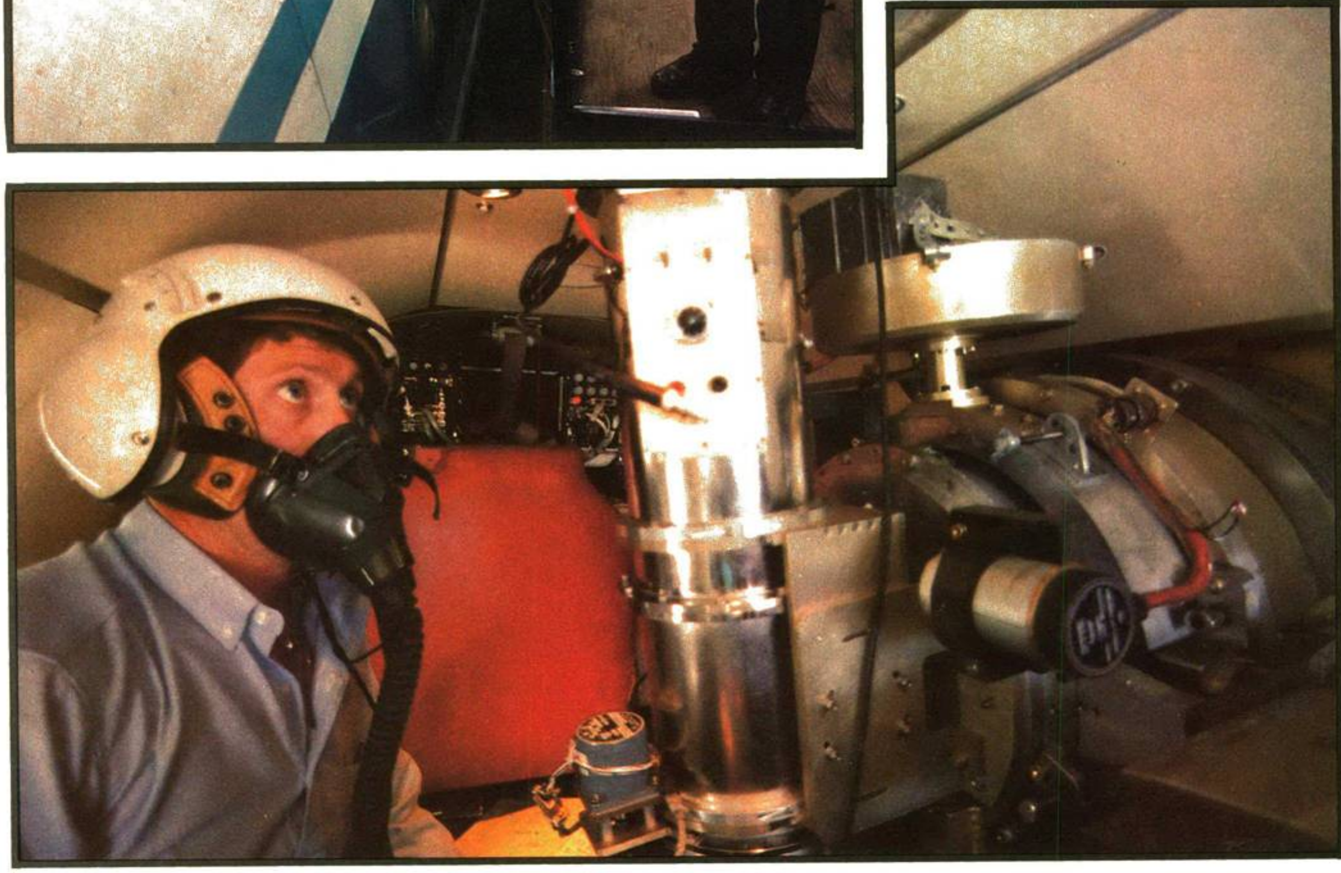
LJO



Above: The black rectangle in the fuselage is the port through which the 36-inch telescope of the Kuiper Airborne Observatory (KAO) views the sky.
Left: The Learjet Observatory (LJO) is smaller than the KAO and carries a 12-inch telescope. Both aircraft take astronomers above most of the water vapor in the atmosphere, enabling them to study the universe at infrared wavelengths. NASA photos, courtesy of the authors.

KAO





LJO

Upper left: Authors Campins (left) and Lynch discuss the KAO's turbulence control system, which is used to modify the airflow past the telescope cavity.
Lower left: On the Learjet, Lynch prepares to take a spectrum of Venus during a daytime flight. The cryogenically-cooled infrared detector is in the tall cylinder (center); the outward-pointing telescope is at right.
Above: A typical scene aboard the KAO during flight. The dangling hoses are for oxygen masks, which are worn whenever the aircraft is above 41,000 feet. Photos courtesy of the authors.

low latitude of the Marshalls (10° north).

The pristine clarity of the stratosphere is, however, a luxury, not a necessity. There is so little water vapor left at 45,000 feet that neither airborne observatory is likely to encounter much difficulty. Besides, all astronomers aboard are grateful just to be there; they know their usual observing sites lie some six miles lower, bathed in the humid murk of the troposphere and blind to most infrared radiation.

What of the target itself? As the most famous of all the "hairy stars," Halley is the brightest of the short-period comets, those comets rather arbitrarily defined as having orbital periods shorter than about 200 years. Even though its impressive appearance during some past visits will not be repeated this time around, there is still tremendous excitement associated with its return. Because Halley's return is so predictable, astronomers around the world have been able to carefully plan experiments that will study the comet using powerful new observing techniques that would be difficult or impossible to apply to any cometary visitor arriving on short notice.

One of these techniques is airborne infrared observations, which sometimes require preparations to start as early as two years before the actual observations. Halley thus marks a comet "first" for the KAO: Although the airborne observatory entered service in 1975, no one has yet applied its capabilities to a comet.

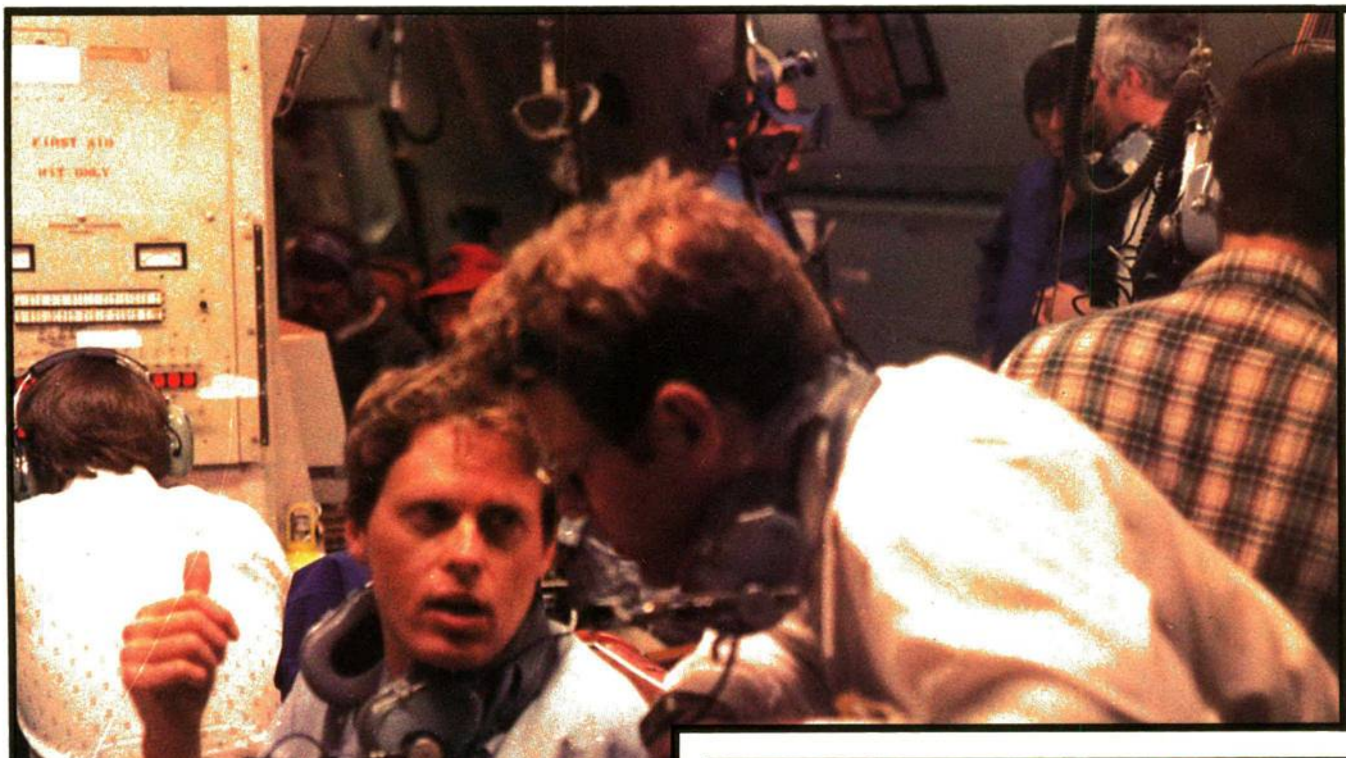
For the cometary astronomer, the infrared region of the spectrum is especially interesting. It is here that radiation from most of the gases produced by the sublimation of the icy nucleus can be observed. When the ices at the surface of the nucleus warm up and sublimate, they give off molecules of gas that have the same composition as the ices, just as dry ice gives off CO_2. However, these "parent molecules" are soon broken up by the Sun's energetic ultraviolet rays to produce radicals or "daughter" fragments. For example, H_2O breaks up into OH plus hydrogen, and HCN becomes CN plus hydrogen. Emissions from CN, C_2, O, NH_2, etc. dominate the visible spectra of most comets.

In order to understand the composition of the ices in the nucleus, it is not enough to study the fragments alone since in most cases there is no way to reassemble them and deduce the composition of the parent molecules. The problem is further complicated because many of those molecules are also abundant in the Earth's atmosphere, where they absorb the light coming from the same chemical species in the comet. By putting most of this light-absorbing atmosphere beneath the telescope an airborne observatory clears the view significantly. In addition, we may discover spectral signatures from other chemical components of the comet whose existence we haven't yet guessed at.

Although gas molecules and fragments produce substantial line emission, small solid particles contribute most of the infrared radiation produced by a comet. Based on the upcoming KAO and LJO observations of Halley's gas and dust, we expect to determine the temperature, composition, size distribution, and total mass of the dust in the comet. We also expect to learn what kinds of molecules are present in the coma and how they interact with each other, with the dust, and with the radiation from the Sun. All of this information will give us new insight into the composition of the comet's nucleus and its relationship to the early solar nebula and interstellar matter.

Because most of the infrared spectrum is invisible from the

KAO



Above: Endless checking and operational readiness — author Lynch (left) and principal investigator R. Russell confer aboard the KAO during a break between observing sessions.

Right: There is only room enough in the rear section of the Learjet for one experimenter. This photo by David Retig shows Lynch at the telescope. Photos courtesy of the authors.

LJO

An Observing Run on the KAO

A typical KAO flight begins with a visit to the navigators. Armed with a list of objects to be observed, the astronomer points out the essential requirements of a project, such as a certain calibrating observation or a particularly long leg for a faint object. After many hours of jousting with the navigation program, a flight plan emerges that optimizes observing time while still keeping the aircraft within national boundaries or away from restricted air space. "Dead" legs are avoided whenever possible and, of course, the last leg must end near home base, whether that's Moffett Field, California (the KAO's main home) or whatever temporary home base is chosen. Later, each leg is broken down into a minute-by-minute schedule.

Immediately after lunch, the flight crew, ground crew, experimenters, navigators, flight directors, and anyone else connected with the flight gather in the hangar for the "one o'clock" meeting. Here final details are nailed down and checked. The facility manager rips through the items on the blackboard, usually with a few jokes at somebody's expense: "What time is takeoff? Are you kidding?" he says to the astronomers. "Why do you guys always want to fly at night? Listen, when you go to Hawaii, I expect some pineapples. Have we started precool? I want you guys to check the tracker power supply. Last night it was so bad it couldn't find the Sun!" He ends the meeting with a rousing "Let's go get the data!"

An hour before takeoff, everyone scheduled to fly attends a preflight briefing held by the mission director. Here attendance is checked, weather conditions are discussed, astronomical goals are summarized, safety rules and procedures are verified, copies of the time line (flight plan) are distributed, and take-off time is updated.

When everyone is aboard and strapped in, the plane takes off and sets a course for the first leg. After climbing the first few thousand feet, everyone is free to unbuckle their seat belts and make sure their equipment is functioning properly. People pick up time lines and check off each item as it is readied. The KAO is not soundproof so the entire interior reverberates like a kettle drum from engine noise. Because of this, everyone wears an intercom headset.

By now, the "acquisition camera" has already zoomed back to take in the widest amount of sky possible and the telescope is preset at the proper elevation. The crew always performs both maneuvers in advance to save time. As soon as the target starfield is identified and the finder camera has zoomed in on the object at highest magnification, the experimenters take control. They carefully position the object and lock the tracker on it or a guide star. Then they check that the detector on the main telescope is receiving the signal from the object, verify gain settings, check the focus one last time, select a chopper mode, and initialize the software.

Finally, after a round-robin check of each team member via the intercom, the principal investigator — the chief scientist aboard — issues the command to begin.

The infrared equivalent of an exposure is an "integration." The telescope and detector instrument stare at the object long enough to collect a statistically meaningful amount of radiation from it. Integrations can last from a few seconds to several minutes, depending on the source's brightness and what the detector instrument is doing to the incoming signal.

Though the air in the cabin is thin and cold, by now you could cut the tension with a knife. There is some joking — and occasional swearing — but each member tends to his equipment and generally talks only when necessary.

For the next seven hours, source after source is observed with quiet, coordinated efficiency. At the end of each leg, everyone dashes for the coffee, the ice box, or the toilet. Only a few minutes are available as the airplane turns slowly from one leg to the next. Then, as the last leg is finished — usually within a minute of the projected time — the principal investigator calls it quits and tells everyone to wrap it up.

While the mighty jet glides gently down toward home base, scientific gear is stowed and everyone relaxes. The plane trembles as the lowered flaps bite the airstream and the landing gear clunks into place.

Finally, NASA 714 (as the air traffic controllers call it) rolls up to the waiting ground crew in front of the hangar and everyone heaves a weary sigh.

It was a good observing run. They got the data.

ground, comet astronomers will be delving into territory that is still largely uncharted. We have drawn some parallels between what we know about interstellar dust grains and what we think goes on in a comet. But how close these educated guesses will come to reality is very much open to question. And, as in the case of the gas molecules, we will probably discover entirely new things.

The airborne observations of Comet Halley promise much. Both planes are equipped with state-of-the-art instruments that are ideally suited for the project. The data produced by these aerial observations will be combined with results from a record number of professional and amateur astronomers who have been almost continuously viewing the comet. Finally, the observing techniques being used aloft have never been applied to comets, but if past experience is any guide, that all but guarantees revolutionary discoveries.

Humberto Campins is an infrared astronomer at the Planetary Science Institute in Tucson, Arizona. David K. Lynch is an astronomer in the Space Sciences Laboratory at Aerospace Corporation in Los Angeles. His main research interests center on protostellar objects and molecular clouds.

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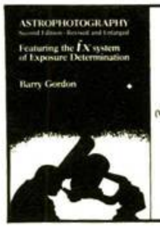
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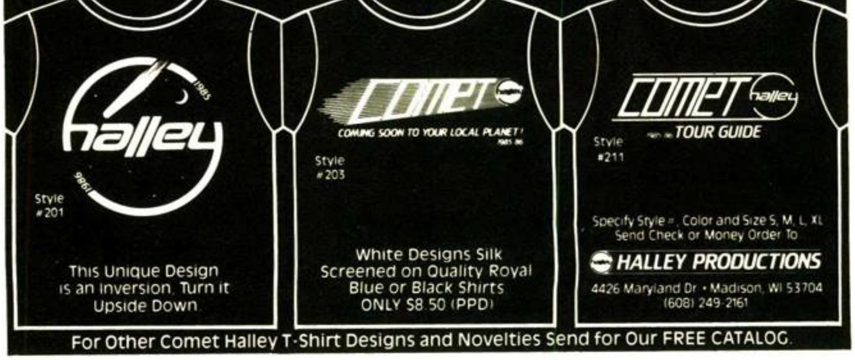

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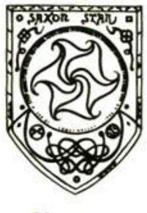

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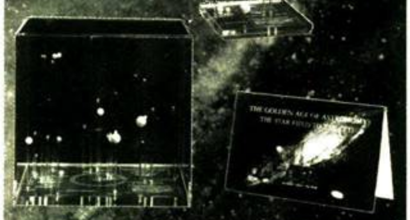

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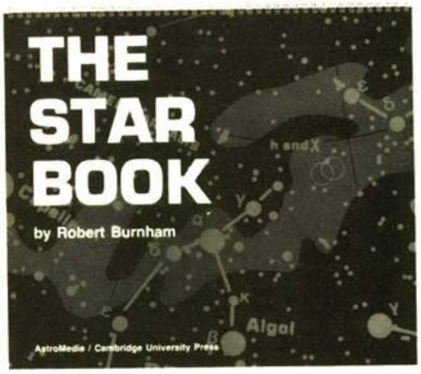
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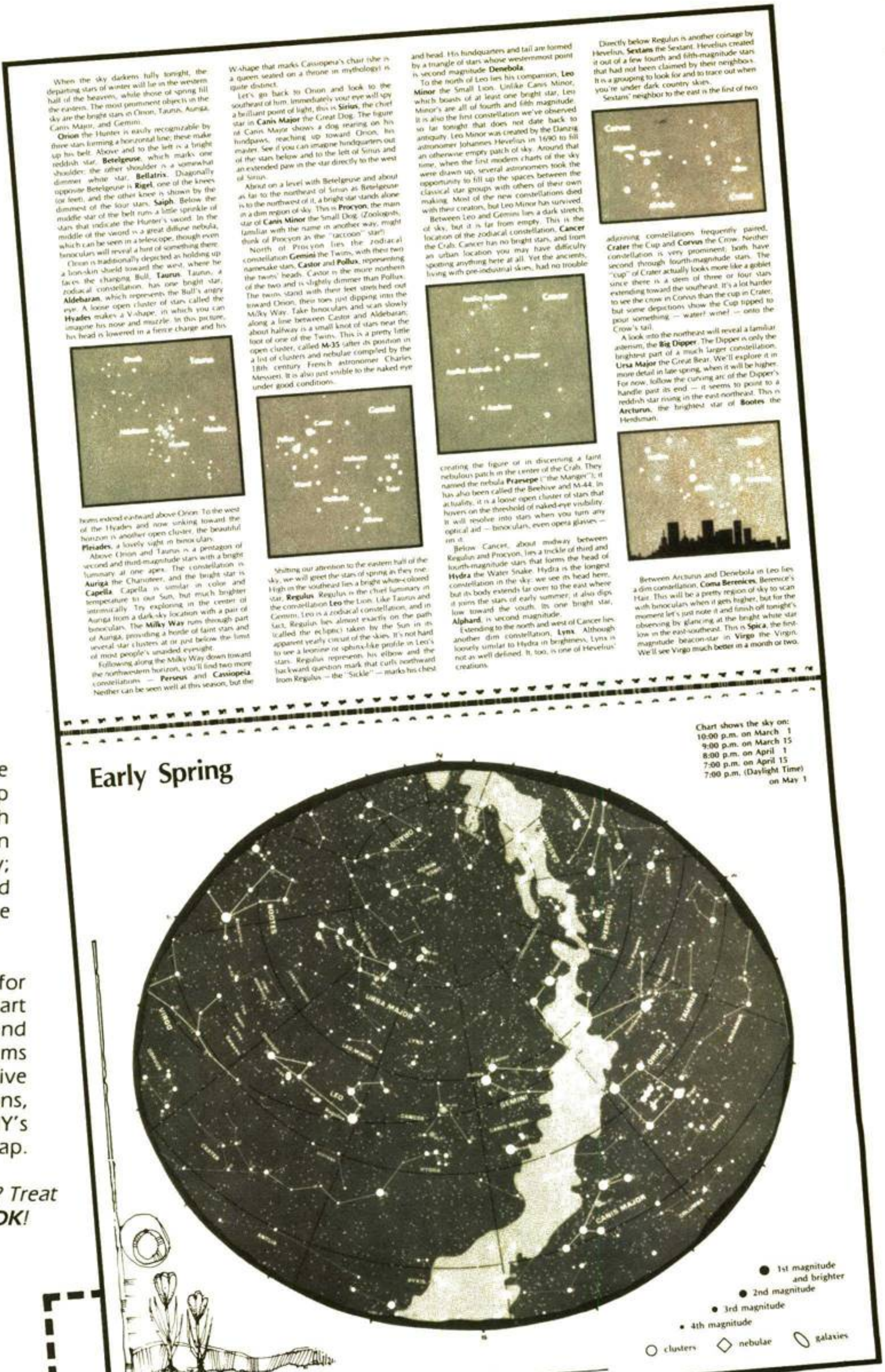
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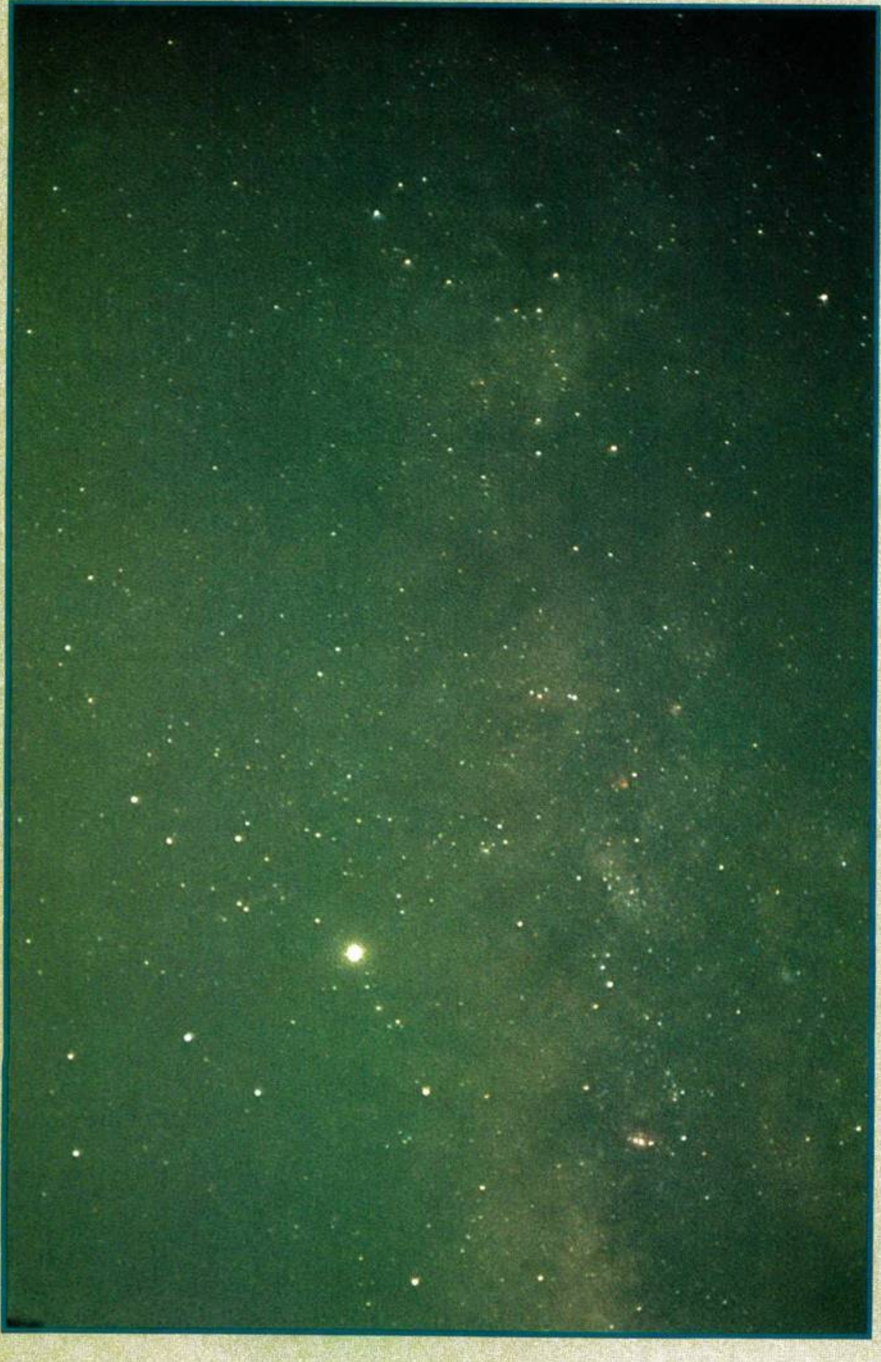
Astrophotography With Your Alt-Azimuth Mounting

by
Gus E. Johnson



Jupiter lay just north of the Teapot in Sagittarius when this photo was taken in March 1984. The lens was a 50mm f/1.9, the film was Kodak's VR 1000, and the exposure ran 90 seconds. Photo by the author.

Yes, you read it right. And I don't mean putting a Dobsonian on a Poncet mount, either. I mean a real, old-fashioned, honest-to-goodness alt-azimuth mounting equipped with nothing fancier than slow motion controls.

Every astrophotographer probably got his or her start using an ordinary camera, fast film, and a tripod. Depending on the lens, you could run exposures up to about 15 seconds this way before the stars trailed too much. This was long enough to show constellations much the way they look to the naked eye, but not quite long enough to bring out Milky Way star clouds or a lovely comet tail.

So unless you can piggyback that camera on an equatorial mounting, you're pretty well out of the starfield astrophoto business, right?

Wrong.

Alt-azimuth mountings can be used for astrophotography, too. These mounts have long been rejected by astrophotographers on two grounds: the tracking rate varies in two axes simultaneously and the field of view rotates. Let's examine these problems individually.

Tracking in two axes is basically a matter of manual dexterity. It never becomes easy, but as long as the slow motions of your alt-az mounting turn smoothly, all you really need is practice. If the control knobs on the mounting are shaped the same, tape something onto one of them so you can tell one from the other by feel in the dark. Then make several high-magnification dry runs. When you're able to hold Arcturus, say, in the center of the field of view at 100x, you're ready for the real thing.

The second problem, field rotation, isn't so tractable, however. There's no way to avoid it, given that you have two coor-

The photos at left show adjoining fields in Libra (top) and Scorpius (below). In the Libra photo, the bright "star" Saturn lies to the upper right of Mars (center). In the lower photo, the bright star is Antares. Both photos were taken with a 50mm f/1.9 lens and VR 1000 film. The Libra photo had a 50-second exposure; Scorpius, 2½ minutes. Photos by the author.

dinate systems (equatorial and horizon) working at cross purposes. Professional telescopes with alt-azimuth mountings (for example, the Russian 6-meter and the American MMT) solve the problem by rotating the instruments at the focal plane or placing a movable prism in the light path to de-rotate the image. But these high-tech solutions aren't practical for us low-tech observers.

You have only one "control" over field rotation: exposure time. Keeping exposures short minimizes the apparent effects since the amount of rotation is directly proportional to the exposure time. How long can you expose? That depends on how much trailing you're willing to accept, but short rotation trails will be evident on 1-minute exposures.

One minute sounds awfully short, but fortunately there are several color films in the 1000-speed class now on the market. Coupled with fast lenses, these let you record an amazing amount in that time. Kodak makes VR 1000 for color prints and Ektachrome P400/800 slide film that can be pushed to ISO 1600 or more. There's also Fuji's HR 1600 for color prints and 3M's 1000 color slide film. Agfa offers ISO 1000 films in transparency and negative forms, too. Which to choose? That's up to you. Experiment a bit, but then pick one or two favorites and stick with them religiously. Don't play film-brand hopscotch or you'll never learn their characteristics very well. And keep records so that you can figure out what went wrong when the photos come back.

Piggybacking your camera on a scope shouldn't pose any real problems. My scope is a Unitron; the company makes a camera bracket that conveniently clamps onto the tube, and other manufacturers offer similar devices for their scopes. Even if yours doesn't, it shouldn't be difficult to contrive something to hold camera and scope together. (Duct tape will do if you're really desperate.)

For guiding, you'll need a cross-hair eyepiece. An illuminated one isn't necessary since you simply put the guide star out of focus and keep the cross hair centered on its image. When you guide a motor-driven equatorial, high magnifications in the guidescope allow you to make corrections before they show on the film. With an alt-azimuth, though, you are hand-guiding in both axes so keep the guiding magnification around 40x to 60x or you'll go crazy trying to keep the cross hairs on the star.

Tracking is easy if the region of sky that you're observing crosses the meridian since the motion is mainly in azimuth. On the other hand, tracking an object near the zenith is just about impossible so wait until that area of sky moves to a more convenient elevation. A field that is rising or setting offers intermediate problems: the sky motion will keep you busy with both controls but, once again, practice will give you confidence.

Ah, you say, but my Dobsonian doesn't *have* slow motion controls. What then? Everything depends on how smoothly your scope can be nudged. With a typical Dobsonian, the altitude motion works easier than the azimuth and both are stickier than they ought to be. The solution is to regularly clean accumulated grunge off the bearing surfaces. Try to adjust them so that the tracking effort in both axes is about the same. If you can't get a very smooth motion, you may have to confine your astrophotography to wide-angle lenses since these will best tolerate guiding glitches of the "push, overshoot, and correct" variety.

The photographs on these pages are my first attempts at alt-azimuth astrophotography. With an exposure of about one minute, field rotation is only barely visible yet there is considerable detail in the Milky Way. One to two minutes on Sagittarius also worked well, and even the 2½-minute shot of southern Ophiuchus and Scorpius doesn't have an overly objectionable degree of field rotation.

You'll soon establish your own standards, but no matter how picky you are, this is a very useful technique. And just the thing for the Year of the Comet, too!

Snapshots into the Eyepiece

Short guided astrophotos aren't the only kind you can make with an alt-azimuth mounting. A few subjects — the Moon, Venus, Jupiter, and Saturn — are bright enough to allow unguided "snapshot" astrophotos.

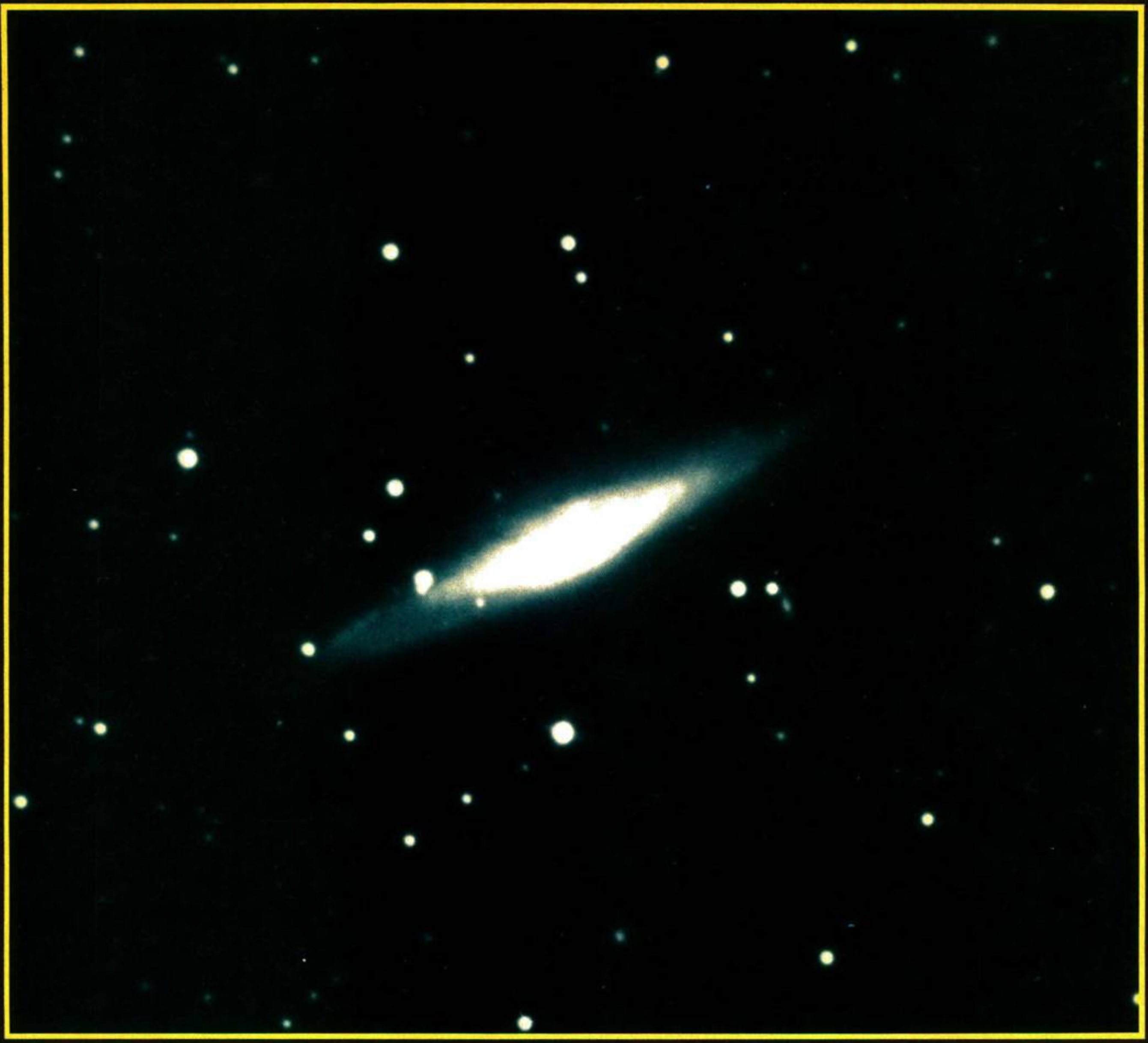
If you own a camera-to-telescope adapter for your SLR, plug the camera body with adapter into the eyepiece holder, focus the telescope, and try a few exposures. The f/ratio of the system is the same as the telescope's optics. If the Moon is the subject, the camera's meter may be able to take a reading. You can also calculate the exposure using the "B" formula (see "Exposure in Astrophotography," January 1985).

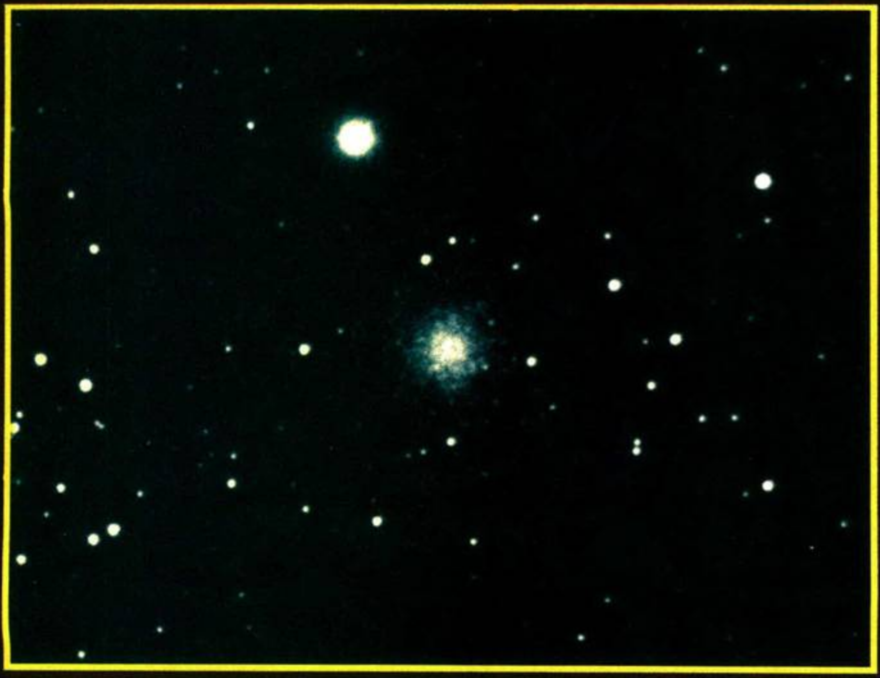
A second popular technique, called the afocal method, requires no adapter (though you may want to use a tripod for stability). Insert an eyepiece into the telescope and focus sharply. Then focus the SLR lens to infinity and point it into the eyepiece, moving it up or down until it's exactly aligned and you can see the entire image clearly in the viewfinder. (That's the tricky part!)

If the camera can't meter the subject, use the "B" formula after computing the effective f/ratio. To do this, multiply the focal length of the camera lens by the magnification that the eyepiece gives, then divide the result by the aperture of the mirror (lens). Remember to keep all units of measure the same, whether inches or millimeters.

Now a few caveats. Eyepiece projection and the afocal method may not always work well. In some cases these techniques make the f/ratio unmanageably slow and force you toward making exposures so long that tracking becomes necessary. Or, what amounts to the same thing, they may increase the image scale so much that the object won't "sit still" for a snapshot. Secondly, some Dobsonian users may find that stopping the aperture down to about 40 percent of full size improves the image quality. If you do this, re-compute the effective f/ratio.

(Jupiter photo by Wally Pursell: 10-inch f/5.6 Dobsonian, 8mm eyepiece, 50mm camera lens, and a $^1/_{15}$-second exposure on ISO 400 film.)

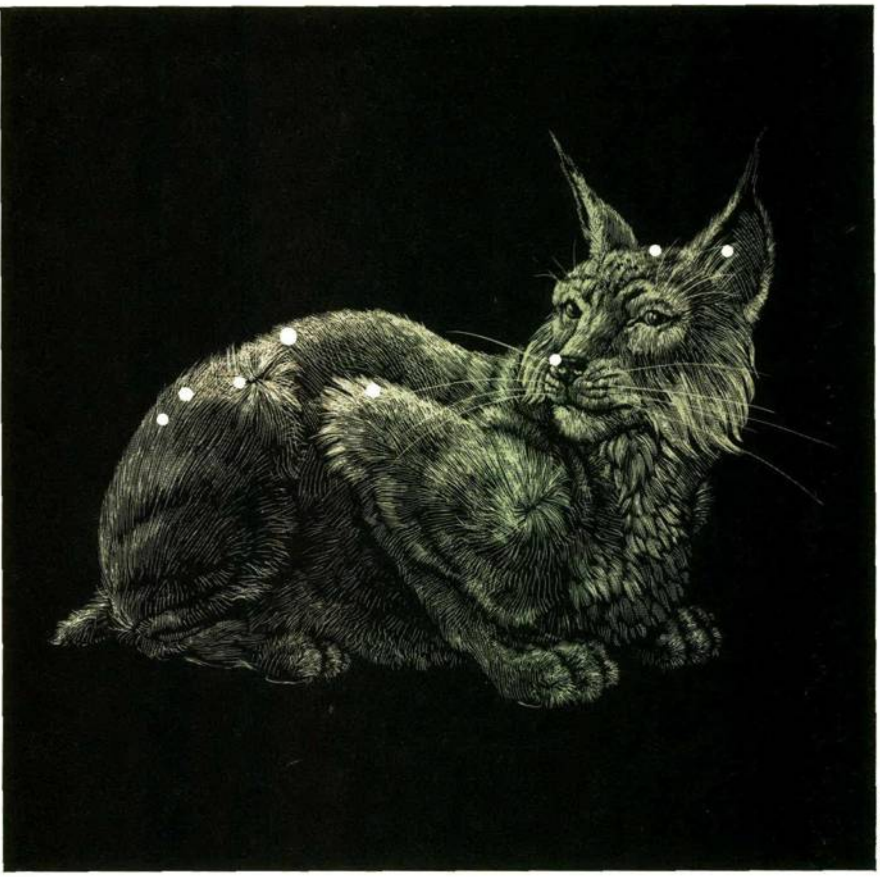




Above: The Sb-type spiral NGC-2683 is one of the brighter springtime galaxies; it reveals subtle spiral structure to owners of medium-sized telescopes. Photo by K. Alexander Brownlee. Left: Located 90 kiloparsecs distant, NGC-2419 is one of the remotest globular clusters visible in backyard telescopes. Photo by Martin C. Germano.

Lynx

Lyn
Lyncis


Keith Ward

Because it is almost invisible to the naked eye, **Lynx** the Lynx is often thought to contain virtually no interesting deep-sky objects. But this faint collection of stars lies on the extreme western edge of a rich cloud of galaxies that stretches from Ursa Major in the north through Virgo in the south. Lynx is home to a number of galaxies that appear quite impressive in small telescopes. The constellation also contains two unusual deep-sky objects: an extremely distant globular cluster and a very large, faint, and challenging planetary nebula.

The finest galaxy in this region of sky is the large Sb-type spiral **NGC-2683**, a galaxy that lies just inside Lynx's border with Cancer. To find this 10th-magnitude misty oval of light, find the star Sigma² (σ^2) Cancri in your finderscope and move the telescope about 2° northwest. A low-power eyepiece should provide a good overall view of NGC-2683, which is inclined at a nearly edge-on angle to our line of sight. With a telescopic aperture of 4-inches or more, you should see a small, thin, bright oval nucleus measuring some 2′ x 0.5′ across. This is enshrouded in a far larger envelope of hazy light spanning 6′ x 1.5′. (The photographic extent of NGC-2683 is 9.3′ x 2.5′.)

Experiment with different eyepieces; since NGC-2683's surface brightness is rather high, it can take fairly high magnification without becoming a featureless blob. With a 10-inch or larger telescope you may detect some of the galaxy's subtle spiral structure, which is fairly easy to see in the largest backyard telescopes (those over 16 inches in aperture). If you have one, try using a blue-sensitive nebula filter on this galaxy. You may get impressive results.

Several smaller galaxies lie in the constellation's northeastern corner. About 2.5° north of the bright star 36 Lyncis is **NGC-2776**. This loosely wound, Sc-type spiral is more distant than NGC-2683 and is situated nearly face-on such that its overall dimensions are 2.9′ x 2.7′. A 6-inch scope trained on NGC-2776 will show a circular fuzzy patch of light with a very slight central condensation. A 12-inch scope shows the galaxy's small bright nucleus surrounded by a 2′ diameter halo of greenish haze. NGC-2776's overall magnitude is 11.6 and its surface brightness is rather low; try to observe this galaxy only on nights when the transparency is good and the Moon is absent.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Moving southward past 36 Lyn and continuing another 3.5° will bring you to the fine Sb-type spiral **NGC-2782**. This galaxy is slightly larger and brighter than NGC-2776, appearing as a dish-shaped oval of light in a 4-inch telescope. A 10-incher reveals a strongly condensed nuclear area wrapped in a uniformly bright halo of nebulosity. Midway between 36 Lyn and NGC-2782 and slightly to the east is the faint, barred spiral **NGC-2798**. This galaxy shines at magnitude 12.3 and spans 2.8′ x 1.1′ across, appearing as a faint oval spot of light in small telescopes. Large backyard telescopes don't show much more detail but do reveal a bright nucleus and show the haze as asymmetrical.

A curious collection of galaxies lies in central Lynx, bracketed by the bright star 31 Lyncis and the double star 27 Lyncis. The most unusual of these, **NGC-2537**, is about 4° northwest of 31 Lyn. NGC-2537 is probably a face-on spiral (its classification is a bit uncertain) measuring 1.7′ x 1.5′ and glowing softly at magnitude 11.7. A 4-inch scope shows this galaxy as a uniformly illuminated, pale roundish patch. Larger telescopes, however, make NGC-2537 more interesting. An 8-incher under a clear, dark sky shows the galaxy evenly lit save for a bright, incomplete ring of nebulosity around its perimeter. A 16-inch scope reveals some knotty structure in this ring and several bright clumps over the galaxy's face. This weird feature gives NGC-2537 its nickname — the "Bear-Paw Galaxy."

If you observe NGC-2537 at low power with a scope of 8 inches or more aperture, you'll probably get an added treat. In the same field lies **IC 2233**, one of the thinnest galaxies visible in backyard telescopes. IC 2233 is a 13th-magnitude barred spiral oriented almost exactly edge-on. Its dimensions are 4.7′ by a slender 0.6′. An 8-inch scope shows it as a hair-thin, silvery needle of milky light. Larger scopes show only a slight central bulge around the nucleus.

About 3° south and a little east of 27 Lyn is the large spiral **NGC-2541**, a galaxy whose relatively high surface brightness makes it visible as an oval-shaped smudge in 3-inch scopes. NGC-2541's total magnitude is 11.8 and its dimensions are 6.6′ x 3.5′, causing it to appear as a large, nebulous halo centered on a bright, compact nucleus in 6 inch and larger telescopes. Nearby is **NGC-2500**, a barred spiral that is 1.5° southwest of 27 Lyn. NGC-2500 is relatively small — 2.9′ x 2.7′ in diameter — but its total magnitude of 11.6 gives it a high surface brightness.

NGC-2549, our last galaxy in Lynx, lies in the constellation's northeastern corner less than a degree west of the bright star 30 Lyncis. This elliptical galaxy measures 4.2′ x 1.5′ and shines at magnitude 11.1. Small telescopes show it as a bright, featureless oval haze in the same field as 30 Lyn. On a dark clear night, try observing NGC-2549 at high power to get 30 Lyn out of the field. This object is a fine example of a bright E6-type elliptical. The galaxy lies at a high enough declination that it remains visible to many Northern Hemisphere viewers for long periods of time.

One of the largest planetary nebulae is located in a blank field of sky some 6° southwest of NGC-2549. This is **Perek-Kohoutek 164-31.1**, a large amorphous mass of greenish white light measuring a whopping 400″ — nearly 7′ — across. This nearby, intrinsically faint planetary has a total magnitude of roughly 14 and a very low surface brightness, making it a good challenge for owners of large backyard scopes and nebula filters. The nebula is easily photographed with long exposures under a moonless sky.

Lynx also contains a variety of double and variable stars. **V Lyncis** is an irregular variable haphazardly flitting between magnitudes 9.5 and 12. **R Lyncis** is a long-period variable that regularly fluctuates between magnitudes 7.2 and 15 over a period of 379 days. When you look at either of these objects, make a sketch showing the relative brightnesses of field stars around them. By making regular observations every few weeks, you'll be able to compile a log detailing each star's behavior.

NGC-2419

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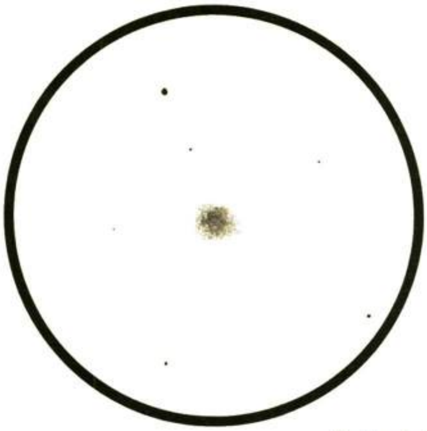
reflector
70x



NGC-2683

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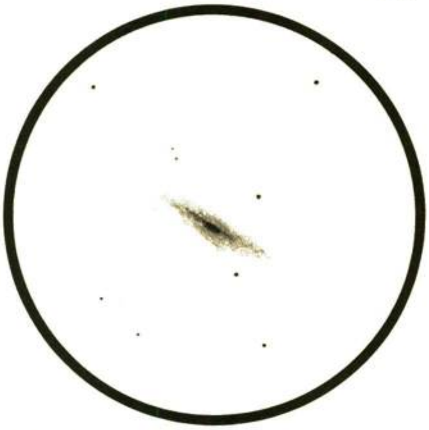
70x



Sketches by David J. Eicher

Easy to find and observe is **38 Lyncis**, a bright triple star just 3° north of Alpha (α) Lyncis in the constellation's southeastern corner. When you find this star, you'll see that it consists primarily of a rather close pair of bright stars with magnitudes of 3.9 and 6.6 (separation 2.7″, p.a. 229°). In the same field of view is an 11th-magnitude star 1½ arc-minutes away at p.a. 212°. All three stars have common proper motions and are, therefore, traveling together through the Galaxy.

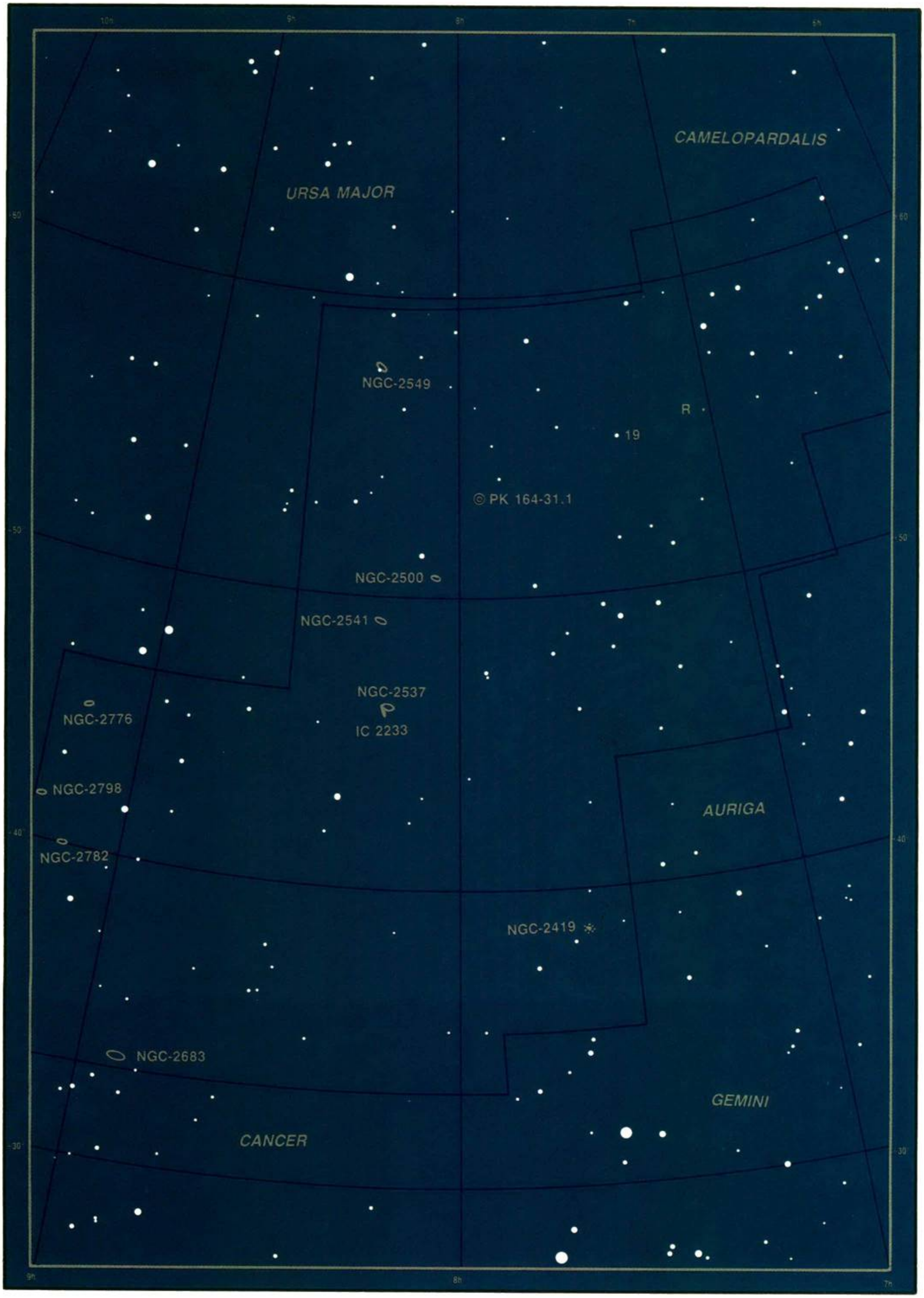
In the northern part of Lynx lies **19 Lyncis**, a fine quadruple star. The main pair is wide and easy in all scopes. It consists of magnitude 5.6 and 6.5 stars separated by 14.8″ at p.a. 315°. About 4′ away at p.a. 3° is a magnitude 8.9 star, and 74.2″ distant at p.a. 287° is an 11th-magnitude member of the same system. This star is a beautiful sight in telescopes both small and large.

One of Lynx's best deep-sky treats is **NGC-2419**, a small globular cluster located in the same field as a 7th-magnitude star at Lynx's southwestern edge. NGC-2419 isn't a tremendous sight as globulars go: it's 4.1′ in diameter and glows feebly at magnitude 10.4. The key word with NGC-2419 is distance — it lies about 90 kiloparsecs away, making it one of the most distant globulars known in the Milky Way. (The entire disk portion of the Galaxy is a mere 35 kiloparsecs across!) Because of its great distance, the eminent astronomer Harlow Shapley dubbed NGC-2419 the "Intergalactic Tramp," believing that it may have broken the gravitational chains of the Milky Way and headed off into deep space. More recent observations, however, indicate that NGC-2419 is moving in a highly eccentric galactic orbit but is destined to remain a member of our local territory in the universe.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
V		IV	6h 29.7m	+61°33′	9.5↔12.0	irr.	
R		LPV	7h 01.3m	+55°20′	7.2↔15	379d	
19		★^{4}	7h 22.9m	+55°17′	5.6,6.5 8.9,10.9	14.8″,214.9″, 74.2″	
NGC-2419		●	7h 38.1m	+38°53′	10.4	4.1′	
P-K 164+31.1		■	7h 57.8m	+53°25′	14p	400″	
NGC-2500		§B	8h 01.9m	+50°44′	11.6	2.9′x2.7′	S$^+$
NGC-2537		§	8h 13.2m	+46°00′	11.7	1.7′x1.5′	S:
IC 2233		§B	8h 14.0m	+45°44′	13.0	4.7′x0.6′	SBd:
NGC-2541		§	8h 14.7m	+49°04′	11.8	6.6′x3.5′	S$^+$
NGC-2549		0	8h 19.0m	+57°48′	11.1	4.2′x1.5′	E6
NGC-2683		§	8h 52.7m	+33°25′	9.7	9.3′x2.5′	Sb$^-$
NGC-2776		§	9h 12.2m	+44°57′	11.6	2.9′x2.7′	Sc
NGC-2782		§	9h 14.1m	+40°07′	11.5	3.8′x2.9′	Sb
NGC-2798		§B	9h 17.4m	+42°00′	12.3	2.8′x1.1′	SBap
38		★^{3}	9h 18.8m	+36°48′	3.9,6.6,10.8	2.7″,87.7″	

H = Hubble classification type for galaxies

★^{3}	*Triple Star*
★^{4}	*Quadruple Star*
LPV	*Long Period Variable*
IV	*Irregular Variable*
●	*Globular Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
0	*Elliptical Galaxy*


10h
9h
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7h
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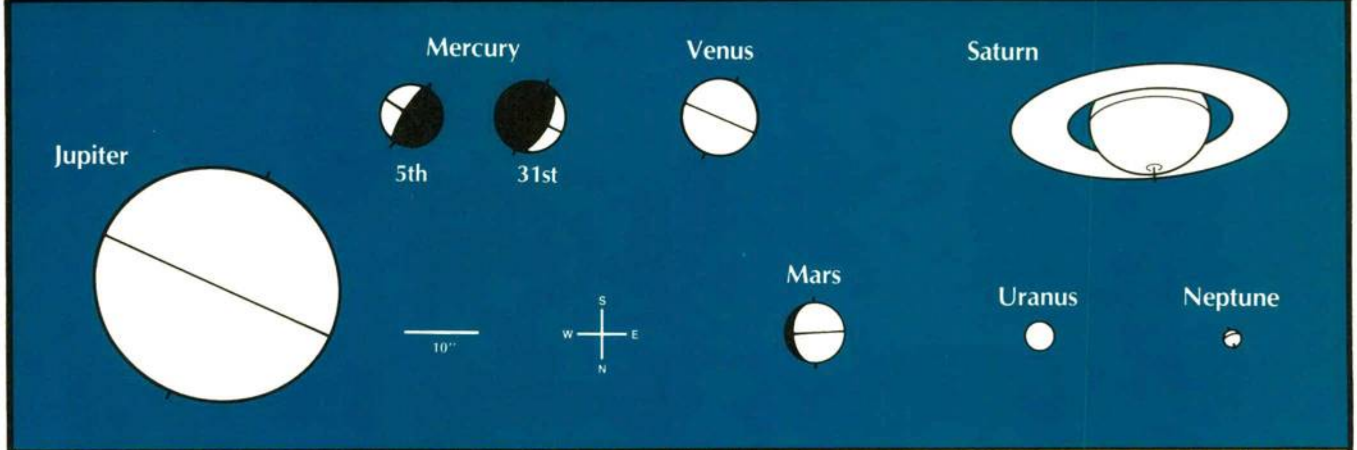
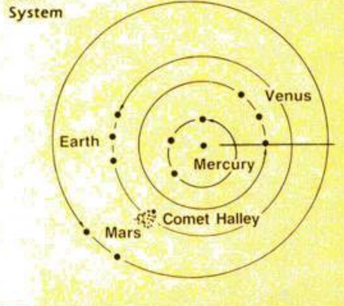
CAMELOPARDALIS
URSA MAJOR
60
60
NGC-2549
R
19
© PK 164-31.1
50
50
NGC-2500
NGC-2541
NGC-2537
IC 2233
NGC-2776
NGC-2798
AURIGA
40
40
NGC-2782
NGC-2419
NGC-2683
GEMINI
CANCER
30
30
9h
8h
7h

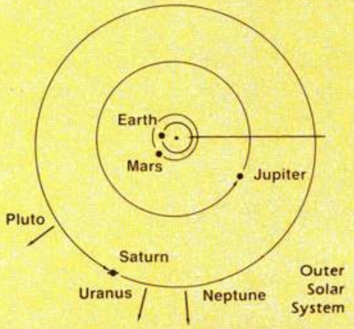
Planetary Data — March 1986


Mercury
5th
31st
Venus
Saturn
Jupiter
10''
S
W
E
N
Mars
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.3′	—	0.99	—	—	340°06.9′	22h 47.3m	− 7°42.6′
		15	−26.8	32.2′	—	0.99	—	—	354°07.1′	23h 39.1m	− 2°15.8′
		31	−26.7	32.1′	—	1.00	—	—	9°59.4′	0h 37.4m	4°01.8′
Mercury	☿	1	−0.3	7.3″	46%	0.92	0.31	92°36.6′	358°22.8′	23h 51.4m	0°52.1′
		15	4.4	10.7″	1%	0.63	0.37	168°15.3′	357°36.8′	23h 46.1m	2°23.8′
		31	1.3	9.9″	23%	0.68	0.45	224°40.0′	348°08.4′	23h 15.9m	− 4°25.7′
Venus	♀	1	−3.9	9.9″	99%	1.68	0.73	3°13.7′	350°03.0′	23h 25.6m	− 5°14.3′
		15	−3.9	10.1″	98%	1.66	0.72	25°32.7′	7°28.9′	0h 29.3m	1°54.3′
		31	−3.9	10.3″	96%	1.61	0.72	51°09.2′	27°18.5′	1h 42.3m	9°54.2′
Mars	♂	10	0.5	7.5″	89%	1.24	1.57	221°14.6′	260°36.7′	17h 19.3m	−22°46.6′
		20	0.4	8.2″	89%	1.14	1.56	226°11.1′	265°58.5′	17h 42.5m	−23°14.3′
Jupiter	♃	15	−2.0	33.1″	100%	5.95	5.02	331°39.8′	335°30.7′	22h 30.6m	−10°17.6′
Saturn	♄	15	0.4	17.1″	100%	9.69	9.98	244°09.1′	249°51.8′	16h 34.2m	−20°00.7′
Uranus	⛢	15	5.6	3.7″	100%	19.07	19.13	259°19.8′	262°20.1′	17h 27.3m	−23°18.1′
Neptune	♆	15	8.0	2.2″	100%	30.43	30.25	273°48.9′	275°45.2′	18h 25.3m	−22°14.1′
Pluto	♇	15	13.7	0.1″	100%	29.03	29.73	215°40.1′	217°08.3′	14h 41.4m	2°08.9′

Inner Solar System


Venus
Earth
Mercury
Comet Halley
Mars

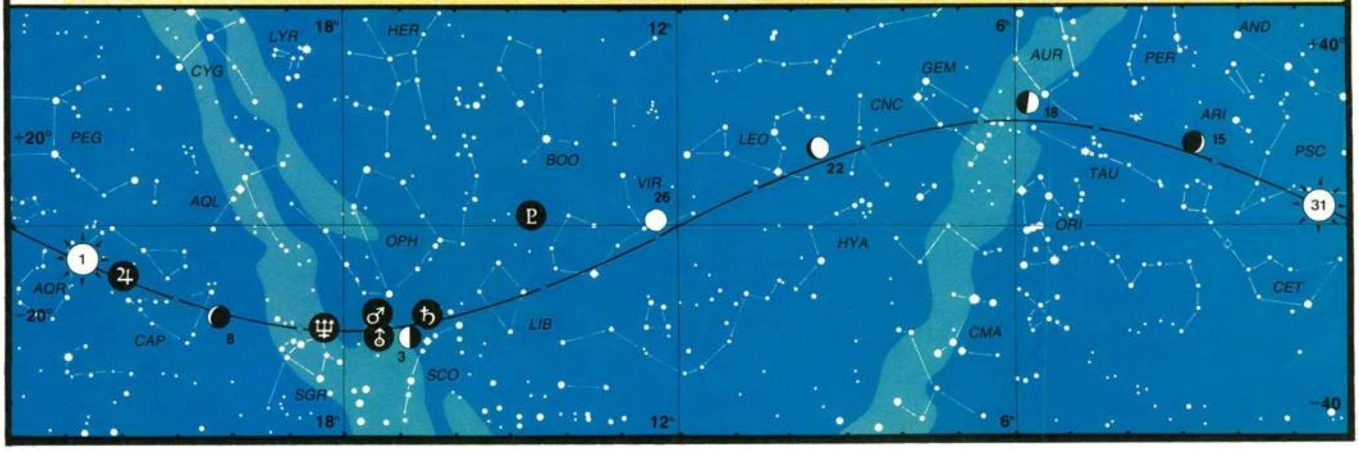

Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune

Outer Solar System

Moon Data

Last Quarter. . . . . .March 3 at 12h17m
New Moon. . . . . .March 10 at 14h52m
First Quarter. . . . . .March 18 at 16h39m
Full Moon. . . . . .March 26 at 3h02m
Last Quarter. . . . . .April 1 at 19h30m

Perigee: March 1 at 9h32m. . . .369,174 km.
Apogee: March 16 at 19h50m. . 404,620 km.
Perigee: March 28 at 13h53m. . 363,958 km.


18h
12h
6h
+40°
+20°
−20°
−40
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HER
PEG
AQL
BOO
VIR
LEO
CNC
GEM
AUR
PER
AND
ARI
PSC
TAU
ORI
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OPH
AQR
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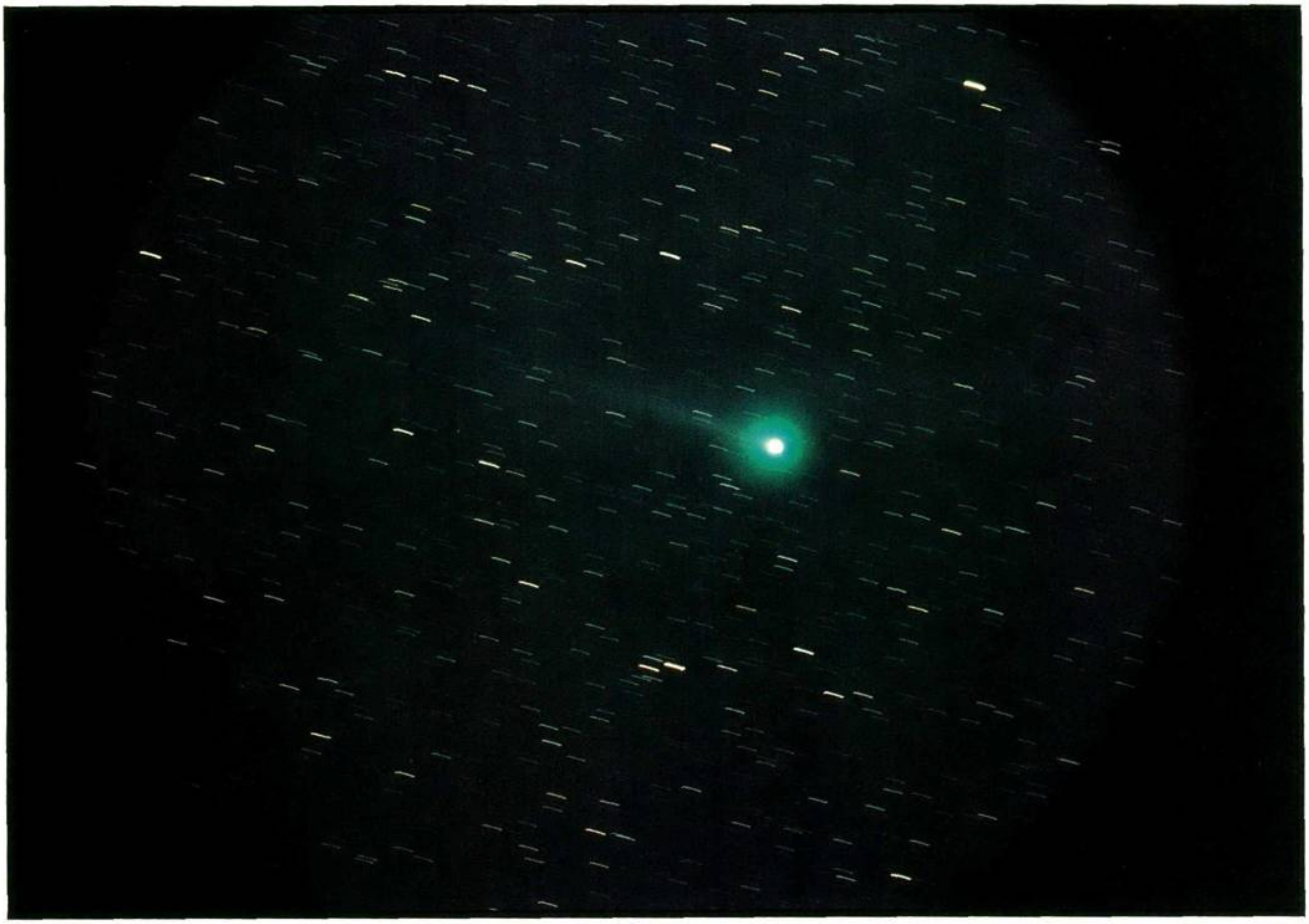


On December 13, 1985, Comet Halley displayed a subtle yet distinct tail. Jim Riffle took this picture with a 12-inch f/5 Astro Mak, hypersensitized Fujichrome 100 film (developed as a negative), and a 45-minute exposure guided on the comet's nucleus.

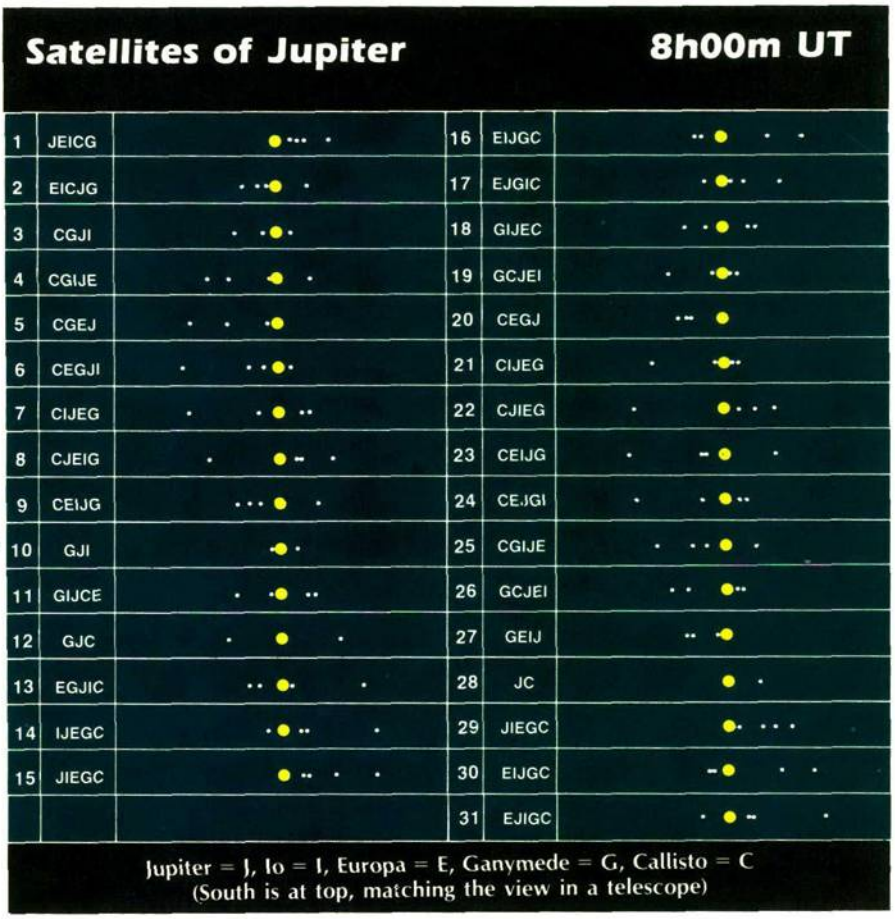
Mercury

For roughly the first week of March, Mercury is visible in the evening sky during the hour after sunset. Starting at an altitude of 9° (45 minutes after sunset) on the 1st, the planet rapidly sinks lower into the evening twilight until it vanishes from view around the 10th. Inferior conjunction with the Sun occurs on the 16th. By late March, Mercury reappears very low in the east before sunrise, but the morning elongation in April will be one of the year's worst.

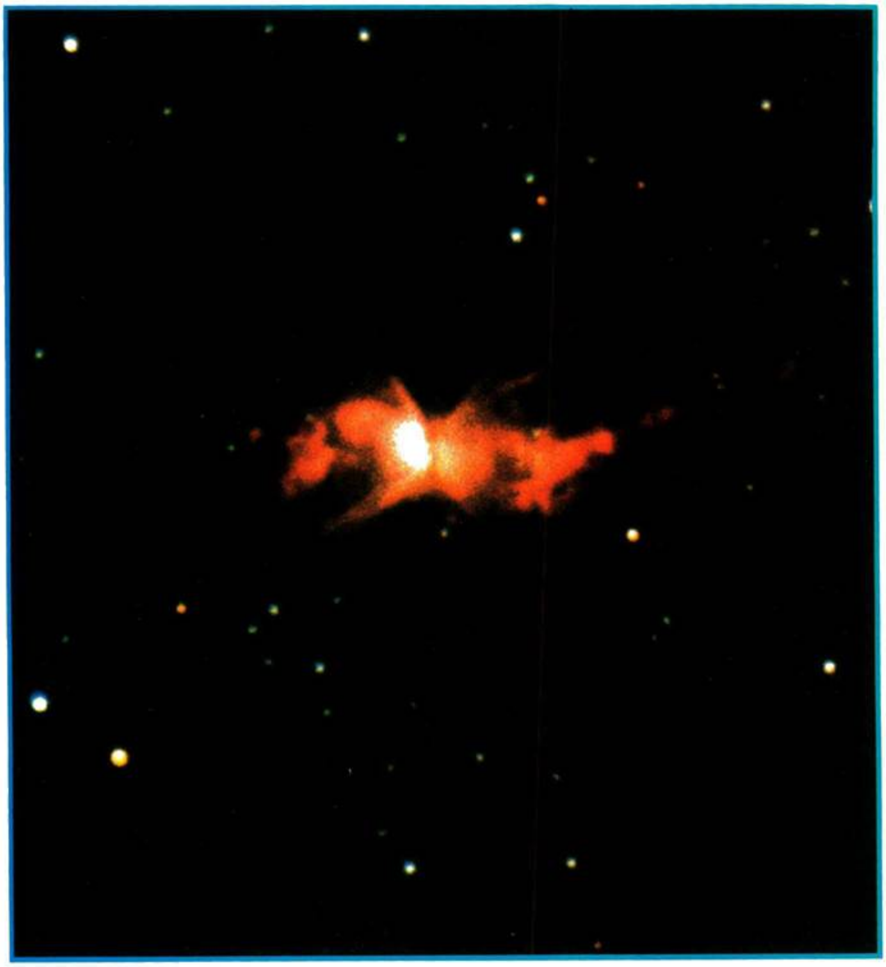
Venus

Emerging slowly from the solar glare into the evening sky, Venus remains low during all of March. The planet can still be found fairly easily, however, due to its −3.9 magnitude brightness. In the evening of the 10th, a slender crescent Moon lies south of Venus, and very low magnifications on a rich-field telescope may let you see them both in the same field of view.

Because Venus is practically on the other side of the Sun from us, it looks small and generally round in a telescope. Between now and early December (when


Satellites of Jupiter
8h00m UT
1 JEICG
2 EICJG
3 CGJI
4 CGIJE
5 CGEJ
6 CEGJI
7 CIJEG
8 CJEIG
9 CEIJG
10 GJI
11 GIJCE
12 GJC
13 EGJIC
14 IJEGC
15 JIEGC
16 EIJGC
17 EJGIC
18 GIJEC
19 GCJEI
20 CEGJ
21 CIJEG
22 CJIEG
23 CEIJG
24 CEJGI
25 CGIJE
26 GCJEI
27 GEIJ
28 JC
29 JIEGC
30 EIJGC
31 EJIGC

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Right: Winner of the March "Best Astro-Photo" award is Howard Zeh. He took this photograph of Bullialdus crater and its surroundings with an 8-inch f/8 Newtonian, eyepiece projection to f/80, and a ¾-second exposure on Plus-X (ISO 125) film. Left: It's not hard to see where the Bug Nebula (NGC-6302) got its nickname. Photo by Jack Marling who used a 24-inch telescope on Mauna Kea, Hawaii, and a 30-minute exposure at f/15 on Fujichrome 400 film developed as a negative.

the planet moves too close to the Sun for observation), you can observe Venus' apparent size growing while its illuminated fraction shrinks. The changes are slow at present but will speed up and become more dramatic by summer.

Earth

On March 20, at 22h03m UT, the center of the Sun's apparent disk will cross the celestial equator in a northbound direction. This marks the equinox and the beginning of northern spring.

Mars

Mars is about 25° high in the south-southeast this month as morning twilight starts to lighten the sky; the planet lies to the northeast of the bright star Antares in Scorpius. On the 13th, Mars lies close to Uranus (see that planet's section for more details). During the last few days of March, Mars passes near three pretty deep-sky objects: M-8 (the Lagoon Nebula), M-20 (the Trifid Nebula), and M-21 (a globular cluster). It will be fun to follow Mars' path as it closes in on them. A week-long sequence of astrophotos will make a stunning demonstration of planetary motion.

Minor Planets

1 Ceres (magnitude 6.8) is moving retrograde in northern Leo. Its positions:

1st: 11h 08m 42s, 23° 51.0′
10th: 11h 00m 48s, 24° 37.7′
20th: 10h 52m 36s, 25° 06.8′
30th: 10h 46m 02s, 25° 10.0′

Ceres is visible all night long.

2 Pallas (8.1) is moving northeastward out of Lepus into southern Monoceros. Its positions:

1st: 5h 51m 20s, −15° 41.0′
10th: 6h 00m 03s, −12° 29.4′
20th: 6h 11m 58s, −9° 06.3′
30th: 6h 25m 52s, −5° 58.6′

Pallas sets around 11:30 p.m. local time on March 15th.

3 Juno (11.0) is nearly stationary in right ascension in central Ophiuchus, where it lies about 5° south of the globular star cluster M-10. Its positions:

1st: 16h 55m 40s, −10° 19.6′
10th: 17h 01m 04s, −9° 49.8′
20th: 17h 05m 28s, −9° 10.5′
30th: 17h 07m 59s, −8° 25.9′

Juno rises about 1 a.m. local time on the 15th.

78 Diana (11.2) is moving westward on the Leo/Sextans border. Its positions:

1st: 11h 12m 54s, 1° 47.6′
10th: 11h 03m 46s, 1° 53.3′
20th: 10h 54m 22s, 2° 01.8′
30th: 10h 46m 56s, 2° 07.3′

Diana is visible all night long.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star atlas (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that has moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Jupiter returns to visibility in the morning this month, but it will be too low for telescopic observation.

Saturn

Saturn's thirty-year circuit of the sky is gradually bringing it into a region that has many celestial sights. All this year, for example, the ringed planet will lie within about 10° of Antares, the ruddy, bright "eye" of Scorpius. Besides observing Saturn with high magnifications, take time now and then to lower the eyepiece power and scan around in its vicinity to see what other sights lie nearby.

This is a perfect time to show the planet to a friend who may never have looked through a telescope before. The northern side of Saturn's rings are tipped toward us at nearly their fullest extent (though they won't reach their maximum until next year).

Uranus

Uranus is in southern Ophiuchus, where it lies about 2° northeast of the 3.3 magnitude star θ Ophiuchi. To locate it, use the finder chart on page 107 of the January 1986 issue or take advantage of Uranus' coincidental conjunction with a far brighter planet — Mars.

On the 13th at 9h31m UT, the center of Mars' disk passes 21′ north of the center of Uranus' disk. At the time of conjunction, Mars will have an apparent size of 7.7″ while Uranus will be 3.7″ across. Mars will have a brightness of 0.5 magnitude, Uranus only 5.6. In your telescope, Mars will look tawny orange while dimmer Uranus will have a pronounced bluish green cast. (The larger the telescope, the more distinctly you will see the color.) Try observing and sketching (or photographing) the conjunction, starting a few days before the event and continuing for an equal time afterward.

Neptune

Neptune is in Sagittarius, a constellation that is about 20° high in the southeast as morning twilight begins to wash out the stars. To find the planet, use the chart on page 107 of the January 1986 issue. Neptune has an 8th-magnitude, 2.2″ disk that looks greenish-gray.

Comet Halley

For complete details on observing Halley, see the Gazer's Gazette beginning on page 46.

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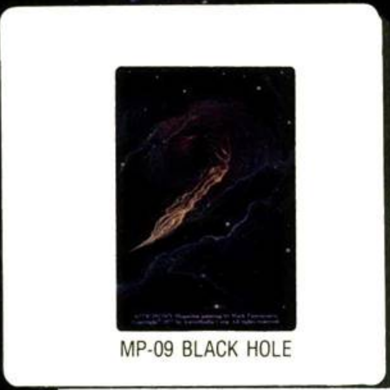

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Crescent Saturn
38
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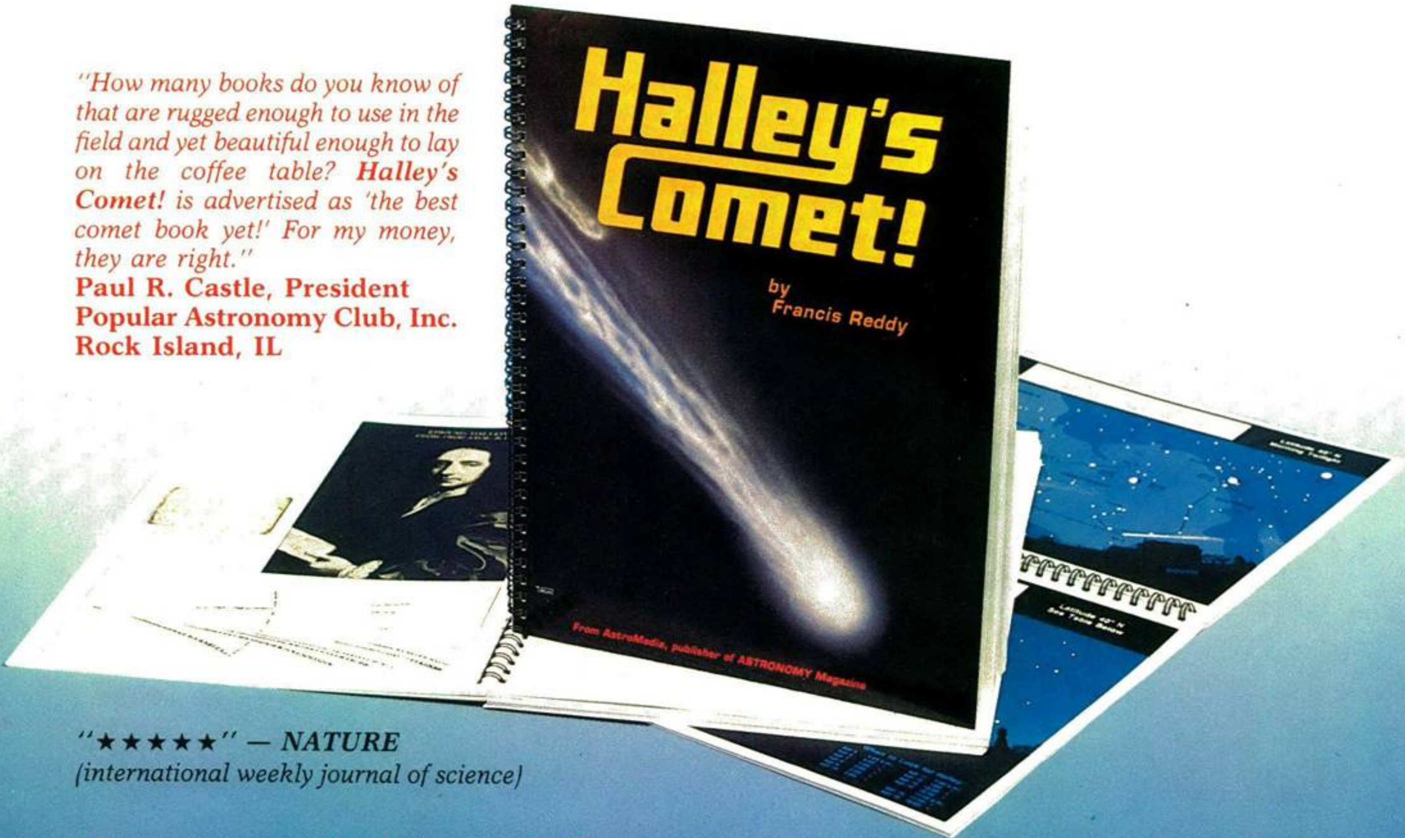

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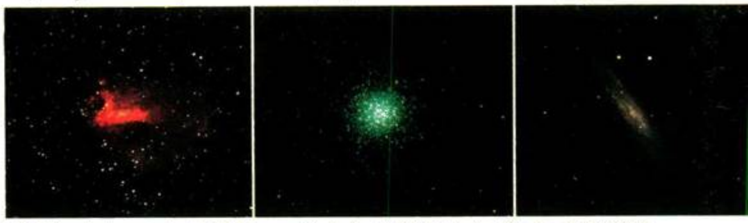

C8 Astrophotographs: M-17, Omega Nebula; M-13, Globular Cluster; NGC-253.

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